S. I. A.

REPORT

OF THE

FIFTIETH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

SWANSEA IN AUGUST AND SEPTEMBER 1880.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1880.

Office of the Association: 22 Albemarle Street, London, W.

LONDON : PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

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OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and*

all future years the privilege of receiving the volumes of the Association *gratis:* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him; and the Secretary of such Society.[1] *Claims under this Rule to be sent to the Assistant Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organizing Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports thereon, and on the order in which it is desirable that they should be

[1] Revised by the General Committee, Sheffield, 1879.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting.* It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association,

read, to be presented to the Committees of the Sections at their first meeting. The[1] Sectional Presidents of former years are *ex officio* members of the Organizing Sectional Committees.

An Organizing Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the General Committee, after which their functions as an Organizing Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the Committee of the Section, and entered on the minutes accordingly.
3. Papers which have been reported on unfavourably by the Organizing Committees shall not be brought before the Sectional Committees.[4]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis

and that he should send it, together with the original Memoir, by book-post, on or before..........................., addressed thus—'General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ....' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. a full three weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and Abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant Secretary, *before the conclusion of the Meeting.*

[1] Added by the General Committee, Sheffield, 1879.
[2] Revised by the General Committee, Swansea, 1880.
[3] Passed by the General Committee, Edinburgh, 1871.
[4] These rules were adopted by the General Committee, Plymouth, 1877.

of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee.[1] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxiii), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they

[1] This and the following sentence were added by the General Committee, 1871.

can be referred to the Committee of Recommendations or confirmed by the General Committee.

The [1] Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next Meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

[1] Passed by the General Committee at Sheffield, 1879.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.

The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stovelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L. F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.

RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.

JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndsean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S. Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. Rev. Dr. Henry. Dr. Andrews, F.R.S. Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S. L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Sir William Thomson, M.A., LL.D., D.C.L., F.R.S. L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S. L. & E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S. L. & E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S. L. & E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
MATHEMATICAL AND PHYSICAL SCIENCES.		
COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.		
1832. Oxford......	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
SECTION A.—MATHEMATICS AND PHYSICS.		
1835. Dublin......	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol......	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool...	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S....	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S............	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork.........	Prof. M'Culloch, M.R.I.A. ...	J. Nott, Prof. Stevelly.
1844. York.........	The Earl of Rosse, F.R.S. ...	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea ...	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place	Presidents	Secretaries
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S.	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. McAlister.
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. McAlister.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

Date and Place	Presidents	Secretaries
1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.

Date and Place	Presidents	Secretaries
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	H. B. Dixon, Dr. W. R. Eaton Hodgkinson, P. Phillips Bedson, J. M. Thomson.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G.B.Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.

Date and Place	Presidents	Secretaries
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin......	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford......	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page xliii.

Date and Place	Presidents	Secretaries
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth...	W. Pengelly, F.R.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham......................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman...	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. xlii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S..........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xlii.

Date and Place	Presidents	Secretaries
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres. R.S.—*Dep. of Anthrop.*, Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.

Date and Place	Presidents	Secretaries
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844 York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S.L.& E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	C. E. Paget, M.D................	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxviii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard......................	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. xl). The Section being then vacant was assigned in 1851 to Geography.

[2] *Vide* note on page xli.

Date and Place	Presidents	Secretaries
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S. L. & E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.

Date and Place	Presidents	Secretaries

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S..........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, Wm. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.

Date and Place	Presidents	Secretaries
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, Frank P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A. ...	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Professor Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.

Date and Place	Presidents	Secretaries
1848. Swansea ...	Rev. Professor Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.........	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	Wm. Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.

List of Evening Lectures.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison..................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.......	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S..........	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.............	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford......	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.......	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S....	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.......	Metallurgical Operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S....	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich ...	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast......	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.............	The present state of Photography.
1854. Liverpool...	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow ...	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson ...	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.

Date and Place	Lecturer	Subject of Discourse
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S.......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S.............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S. ...	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S....	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S...............	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton ...	Prof. P. Martin Duncan, M.D., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S............	The new Element, Gallium.

Date and Place	Lecturer	Subject of Discourse
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S..........	Mental Imagery.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.

OFFICERS OF SECTIONAL COMMITTEES PRESENT AT THE SWANSEA MEETING.

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President.—Professor W. Grylls Adams, M.A., F.R.S., F.G.S., F.C.P.S.

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Vice-Presidents.—Sir Henry Barkly, G.C.M.G., K.C.B., F.R.S., F.R.G.S.; Francis Galton, M.A., F.R.S., F.R.G.S.; Admiral Sir Erasmus Ommanney, C.B., F.R.S., F.R.A.S., F.R.G.S.; Lieut.-General Sir H. E. L. Thuillier, C.S.I., R.A., F.R.S., F.R.G.S.

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Secretaries.—A. T. Atchison, M.A. (Recorder); H. Trueman Wood, B.A.

THE GENERAL TREASURER'S ACCOUNT from August 20, 1879 (commencement of SHEFFIELD Meeting), to August 25, 1880. Not including receipts at Swansea Meeting.

1879–80. RECEIPTS.	£	s.	d.
To Balance from last Account, Sheffield Meeting	39	11	0
Received for Life Compositions at Sheffield Meeting and since	260	0	0
" Annual Subscriptions ditto ditto	603	0	0
" Associates' Tickets ditto ditto	522	0	0
" Ladies' Tickets ditto ditto	351	0	0
" Dividends on Stock	257	0	8
" Sale of Publications	197	6	3
Sundry small sums for Transmission of Papers to Members during Sheffield Meeting	7	12	6
Received for Rent from Mathematical Society, year ending September 29, 1879	12	15	0
By sale of £500 Consols at 99¼ per cent., less 12*s.* 6*d.* commission	495	12	6
By unexpended Grant made at the Glasgow Meeting, 1876, to Mr. F. Clowes, for 'Action of Ethyl-Bromobutyrate on Ethyl Sodaceto-acetate'	10	0	0
	£2755	17	11

1879–80. PAYMENTS.	£	s.	d.	£	s.	d.
Paid Expenses of Sheffield Meeting, also Sundry Printing, Binding, Advertising, and Incidental Expenses				266	13	2
" Messrs. Spottiswoode & Co.'s account for printing for the year 1879–80, Report of 49th Meeting, Vol. XLVIII. (Sheffield)				667	11	9
" Salaries (1 year)				470	0	0
" Rent and Office Expenses (Albemarle Street—1 year)				117	0	0
" Grants made at Sheffield Meeting:—	£	s.	d.			
New Form of High Insulation Key	10	0	0			
Underground Temperature	10	0	0			
Determination of the Mechanical Equivalent of Heat	8	5	0			
Elasticity of Wires	50	0	0			
Luminous Meteors	30	0	0			
Lunar Disturbance of Gravity	30	0	0			
Fundamental Invariants	8	5	0			
Laws of Water Friction	20	0	0			
Specific Inductive Capacity of Sprengel Vacuum	20	0	0			
Completion of Tables of Sun-heat Coefficients	50	0	0			
Instrument for Detection of Fire-damp in Mines	10	0	0			
Inductive Capacity of Crystals and Paraffines	4	17	7			
Report on Carboniferous Polyzoa	10	0	0			
Caves of South Ireland	10	0	0			
Viviparous Nature of Ichthyosaurus	10	0	0			
Kent's Cavern Exploration	50	0	0			
Geological Record	100	0	0			
Miocene Flora of the Basalt of the North of Ireland	15	0	0			
Underground Waters of Permian Formations	5	0	0			
Record of Zoological Literature	100	0	0			
Table at Zoological Station at Naples	75	0	0			
Investigation of the Geology and Zoology of Mexico	50	0	0			
Anthropometry	50	0	0			
Patent Laws	5	0	0			
				731	7	7
Balance at Bank of England, Western Branch	£473	12	11			
In hands of Assistant to General Treasurer	£29	12	6			
				503	5	5
				£2755	17	11

A. W. WILLIAMSON.

August 25, 1880.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ..	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
						£ s. d.	£ s. d.	
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets of Admission to Sections only. ‡ Including Ladies.

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ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology.

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REPORT OF THE COUNCIL.

Report of the Council for the year 1879–80, *presented to the General Committee at Swansea, on Wednesday, August* 25, 1880.

The Council have received Reports during the past year from the General Treasurer, and his account for the year will be laid before the General Committee this day.

The Council having been requested by the General Committee at Sheffield to take such further action as regards the correspondence with the Treasury about the Natural History Collections as they should think desirable in the interests of science, have prepared and sent to the Secretary of the Treasury, in reply to his letter of July 22, 1879, the following letter :—

British Association for the Advancement of Science,
22 Albemarle Street, London, W.
June 8, 1880.

Sir,—The letter of the Council of this Association, of March 25, 1879, respecting the administration of the Natural History Collections, and your reply thereto of July 22, have been laid before the British Association, at the meeting held at Sheffield in August last, when the subject was again referred to the Council.

On the part of the Council I am now requested to inform you that they learn with satisfaction that the action of Her Majesty's Government, in passing the British Museum Act of 1878, does not prejudice the question of the future administration of the Natural History Collections at South Kensington, but that the subject is still under the consideration of the Lords Commissioners of Her Majesty's Treasury.

Under these circumstances, the Council of the Association must again express their hope that, when the period arrives, as it must shortly do, for the settlement of the question, the recommendations of the Royal Commission on Science will have their full weight and importance accorded to them.

If, however, the Lords Commissioners of Her Majesty's Treasury are prepared, as they would seem to indicate, to constitute a Special Standing Committee, or Sub-Committee, of the Trustees of the British Museum, for the management of the Natural History Collections, the Council of the Association are of opinion that such a form of government, though not the form suggested by the Royal Commission on Science, might possibly be so organised as to be satisfactory both to the public and to men of science.

Trusting that the Lords Commissioners will do the Council the favour

of considering these observations on a subject which keenly interests many members of the British Association,

I have the honour to be, Sir,

Your obedient servant,

G. J. Allman,

President of the British Association for the Advancement of Science.

Sir R. R. W. Lingen, K.C.B., &c. &c.

The receipt of this letter has been acknowledged.

A letter having been received from the Secretary of the Anthropometric Committee, requesting that the Council would address a Memorial to the Education Department, requesting the Department to assist the Committee in obtaining certain statistics as to the development of children in Board Schools, it was resolved that a Committee, consisting of Dr. Beddoe, Mr. Francis Galton, Mr. Heywood, and the General Officers, should be appointed to consider the subject and to report to the Council thereon. Owing to the unavoidable absence of several of the members, the Committee have as yet been unable to make any report to the Council upon the subject.

The Council have resolved, on the request of the Tidal Observation Committee, that the best thanks of the Association be given to the First Lord of the Admiralty, the President of the Board of Trade, the French Minister of Public Works, the Belgian Minister of Public Works, and to the several other authorities and private individuals, both in this country and on the Continent, who have kindly and gratuitously had the various observations carried out and communicated to this Committee; and more especially to the French Association for the Advancement of Science for its cordial assistance in supporting the proposal of the British Association, and in urging it upon the French Minister of Public Works.

The Council have to announce that they have elected Professor Cornu, of Paris, and Professor Boltzmann, of Vienna, Corresponding Members, since the Sheffield meeting.

Applications for free or 'exchange' copies of the Reports of the Association being from time to time received, the Assistant Secretary has been directed to reply to such applications: 1. That a few remaining sets from 1831 to 1874 can be supplied at 10*l*. per set, and all other volumes between 1831 and 1874 which are in stock at 2*s*. 6*d*. per volume net. 2. That all volumes after 1874 can be supplied at the publication price of 24*s*. per volume. 3. That the Reports for 1839 and 1840 are out of print, and that only a very few copies remain of those for 1833, 1838, and 1850.

As the Committee are aware, the Association have already determined to hold the Meeting for 1881 at York, and thus to commence the second half-century of their existence in the same city as that in which the Association was founded in 1831.

For 1882 and the following years invitations are expected to be presented at the present meeting from Southport, Southampton, Nottingham and Leicester.

The Council propose that, in accordance with the regulations, the five retiring members shall be the following:—

Barlow, W. H., Esq., F.R.S.
Lefevre, G. Shaw, Esq., M.P., F.R.G.S.
Maskelyne, Prof. N. S., M.P., F.R.S.
Ommanney, Admiral Sir E., C.B., F.R.S.
Russell, Dr. W. J., F.R.S.

The Council recommend the re-election of the other ordinary members of Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Abel, F. A., Esq., C.B., F.R.S.
Adams, Professor W. G., F.R.S.
*Bateman, J. F., Esq., C.E., F.R.S.
Cayley, Professor, F.R.S.
Easton, E., Esq., C.E.
Evans, Captain, C.B., F.R.S.
Evans, J., Esq., F.R.S.
Foster, Professor G. C., F.R.S.
Glaisher, J. W. L., Esq., F.R.S.
Heywood, J., Esq., F.R.S.
Huggins, W., Esq., F.R.S.
Hughes, Professor T. McK., M.A.
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Newton, Professor A., F.R.S.
*Pengelly, W., Esq., F.R.S.
*Perkin, W. H., Esq., F.R.S.
*Pitt-Rivers, General A., F.R.S.
Rayleigh, Lord, F.R.S.
Rolleston, Professor, F.R.S.
Roscoe, Professor H. E., F.R.S.
Sanderson, Professor J. S. Burdon, F.R.S.
Smyth, Warrington W., Esq., F.R.S.
Sorby, H. C., Esq., F.R.S.
*Thuillier, General Sir H. E. L., C.S.I., F.R.S.

Recommendations adopted by the General Committee at the Swansea Meeting in August and September, 1880.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the Committee, consisting of Mr. G. H. Darwin, Professor Sir William Thomson, Professor Tait, Professor Grant, Dr. Siemens, Professor Purser, Professor G. Forbes, and Mr. Horace Darwin, be reappointed for the Measurement of the Lunar Disturbance of Gravity; that Mr. G. H. Darwin be the Secretary, and that the sum of 30*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Professor Everett, Professor Sir William Thomson, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. Pengelly, Professor Edward Hull, Dr. Clement Le Neve Foster, Professor A. S. Herschel, Mr. G. A. Lebour, Mr. A. B. Wynne, Mr. Galloway, Mr. Joseph Dickinson, and Mr. G. F. Deacon, on Underground Temperature be reappointed, with the addition of the name of Mr. A. Strahan; that Professor Everett be the Secretary, and that the sum of 20*l.* be placed at their disposal.

That Professor G. Carey Foster, Mr. C. Hockin, Professor Sir William Thomson, Professor Ayrton, Mr. J. Perry, Professor W. G. Adams, Lord Rayleigh, Professor F. Jenkin, Dr. O. J. Lodge, Dr. John Hopkinson, Dr. Muirhead, and Mr. W. H. Preece be a Committee for the purpose of constructing and issuing practical Standards for use in Electrical Measurements; that Dr. Muirhead be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Mr. James Glaisher, Dr. Flight, Professor R. S. Ball, Mr. E. J. Lowe, and Professor A. S. Herschel, on Luminous Meteors be reappointed; that Professor A. S. Herschel be the Secretary, and that the sum of 15*l.* be placed at their disposal.

That the Committee, consisting of Dr. Joule, Professor Sir William Thomson, Professor Tait, and Professor Balfour Stewart, for effecting the Determination of the Mechanical Equivalent of Heat be reappointed; that Dr. Joule be the Secretary, and that the sum of 40*l.* be placed at their disposal for the purpose.

That a Committee, consisting of Dr. O. J. Lodge, Professor Ayrton, and Mr. Perry, be reappointed for the purpose of devising and constructing an improved form of High Insulation Key for Electrometer Work; that Dr. O. J. Lodge be the Secretary, and that the sum of 5*l.* be placed at their disposal for the purpose.

That the Committee, consisting of Professor Sylvester, Professor Cayley, and Professor Salmon, for the Calculation of Tables of the

Fundamental Invariants of Algebraic Forms be reappointed; that Professor Sylvester be the Secretary, and that the sum of 40*l.* be placed at their disposal for the purpose.

That Sir William Thomson, Mr. Robert Boag Watson, and Professor John Young be a Committee for the purpose of making Seismic Experiments in connexion with the great Gunpowder Blasts on Loch Fyne; that Professor Young be the Secretary, and that the sum of 30*l.* be placed at their disposal for the purpose.

That the Committee on Tidal Observations in the English Channel and in the North Sea, consisting of Sir William Thomson, Dr. J. Merrifield, Professor Osborne Reynolds, Captain Douglas Galton, Mr. J. N. Shoolbred, Mr. J. F. Deacon, and Mr. Rogers Field, be reappointed for the purpose of making a final report; that Mr. J. N. Shoolbred be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Mr. J. M. Thomson and Mr. J. E. H. Gordon be appointed a Committee to continue Researches on the Specific Inductive Capacity of certain Crystals and Paraffines; that Mr. J. E. H. Gordon be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Dr. J. H. Gladstone, Dr. W. R. E. Hodgkinson, Mr. W. Carleton Williams, and Dr. P. P. Bedson be a Committee for the purpose of investigating the Method of Determining the Specific Refraction of Solids from their Solutions; that Dr. P. P. Bedson be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor Dewar, Dr. Williamson, Dr. Marshall Watts, Captain Abney, Mr. Stoney, Professor W. N. Hartley, Professor McLeod, Professor Carey Foster, Professor A. K. Huntington, Professor Emerson Reynolds, Professor Reinold, Professor Liveing, Lord Rayleigh, Dr. Arthur Schuster, and Mr. W. Chandler Roberts be reappointed a Committee for the purpose of reporting upon the present state of our knowledge of Spectrum Analysis; that Mr. W. Chandler Roberts be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor P. M. Duncan and Mr. G. R. Vine be reappointed a Committee for the purpose of reporting on the British Fossil Polyzoa; that Mr. Vine be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Dr. J. Evans, the Rev. J. F. Blake, Professor T. G. Bonney, Mr. W. Carruthers, Mr. F. Drew, Professor G. A. Lebour, Professor L. C. Miall, Mr. F. W. Rudler, Mr. E. B. Tawney, Mr. W. Topley, and Mr. W. Whitaker be reappointed a Committee for the purpose of carrying on the Geological Record; that Mr. Whitaker be the Secretary, and that the sum of 100*l.* be placed at their disposal for the purpose.

That Professor E. Hull, the Rev. H. W. Crosskey, Captain Douglas Galton, Mr. James Glaisher, Professor G. A. Lebour, Mr. W. Molyneux, Mr. G. H. Morton, Mr. W. Pengelly, Professor J. Prestwich, Mr. James Plant, Mr. James Parker, Mr. I. Roberts, Mr. S. Stooke, Mr. G. J. Symons, Mr. W. Whitaker, and Mr. C. E. De Rance be reappointed a Committee for the purpose of investigating the Circulation of the Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations of England, and the Quality and Quantity of the Water supplied to various towns and districts from these formations; that Mr. C. E. De Rance be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor A. C. Ramsay and Professor John Milne be a Committee for the purpose of investigating the Earthquake Phenomena of Japan; that Professor Milne be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Dr. H. C. Sorby, Professor W. J. Sollas, and Professor William Ramsay be a Committee for the purpose of investigating the Conditions under which ordinary Sedimentary Materials may be converted into Metamorphic Rocks; that Professor Sollas be the Secretary, and that the sum of 10*l.* be placed at their disposal for the purpose.

That Professor W. C. Williamson, and Mr. W. H. Baily be reappointed a Committee for the purpose of Collecting and Reporting upon the Tertiary Flora, &c., of the Basalt of the North of Ireland; that Mr. Baily be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose, on the understanding that a collection of representative Fossils obtained be sent to the British Museum.

That Dr. M. Foster, Professor Rolleston, Dr. Pye-Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn Jeffreys, Mr. F. M. Balfour, Sir Wyville Thomson, Professor Ray Lankester, Professor Allman, and Mr. P. Sladen be a Committee for the purpose of aiding in the maintenance of the Scottish Zoological Station; that Mr. P. Sladen be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Dr. M. Foster, Professor Rolleston, Mr. Dew Smith, Professor Huxley, Dr. Carpenter, Dr. Gwyn Jeffreys, Mr. Sclater, Mr. F. M. Balfour, Sir Wyville Thomson, Professor Ray Lankester, Professor Allman, and Mr. P. Sladen be reappointed a Committee for the purpose of arranging for the Occupation of a Table at the Zoological Station at Naples; that Mr. P. Sladen be the Secretary, and that the sum of 75*l.* be placed at their disposal for the purpose.

That Lieut.-Colonel H. H. Godwin-Austen, Dr. G. Hartlaub, Sir J. Hooker, Dr. Günther, Mr. Seebohm, and Mr. Sclater be a Committee for the purpose of investigating the Natural History of Socotra; that Mr. Sclater be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Dr. Gwyn Jeffreys, Professor Sir Wyville Thomson, and Mr. Percy Sladen be a Committee for the purpose of a Zoological Exploration of the Seabed lying north of the Hebrides; that Dr. Gwyn Jeffreys be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Major-General Pitt-Rivers and Mr. A. W. Franks be a Committee for the purpose of issuing a revised edition of the Anthropological Notes and Queries for the Use of Travellers; that Major-General Pitt-Rivers be the Secretary, and that the sum of 20*l.* be placed at their disposal for the purpose.

That Dr. Pye-Smith, Professor M. Foster, and Professor Burdon Sanderson be reappointed a Committee for the purpose of investigating the Influence of Bodily Exercise on the Elimination of Nitrogen (the experiments to be conducted by Mr. North); that Professor Burdon Sanderson be the Secretary, and that the sum of 50*l.* be placed at their disposal for the purpose.

That Professor Rolleston, Professor Allman, General Pitt-Rivers, Mr. J. Evans, and Mr. E. Cunnington be a Committee for the Investigation of Prehistoric Remains in Dorsetshire; that Professor Rolleston be the Secretary, and that the sum of 25*l.* be placed at their disposal for the purpose.

That Mr. Sclater, Mr. Howard Saunders, and Mr. Thiselton-Dyer be a Committee for the purpose of investigating the Natural History of Timor-lant; that Mr. Thiselton-Dyer be the Secretary, and that the sum of 50*l*. be placed at their disposal for the purpose.

That Mr. Stainton, Sir John Lubbock, and Mr. E. C. Rye be reappointed a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of 100*l*. be placed at their disposal for the purpose.

That Mr. F. Galton, Dr. Beddoe, Mr. Brabrook, Sir George Campbell, Dr. Farr, Mr. F. P. Fellows, Major-General A. Pitt-Rivers, Mr. J. Park Harrison, Mr. James Heywood, Mr. P. Hallett, Professor Leone Levi, Dr. F. A. Mahomed, Dr. Muirhead, Sir Rawson Rawson, Mr. Charles Roberts, and Professor Rolleston be a Committee for the purpose of continuing the collection of observations on the Systematic Examination of Heights, Weights, &c., of Human Beings in the British Empire, and the publication of photographs of the Typical Races of the Empire; that Mr. Brabrook be the Secretary, and that the sum of 30*l*. be placed at their disposal for the purpose.

That Mr. Bramwell, Dr. A. W. Williamson, Professor Sir William Thomson, Mr. St. John Vincent Day, Dr. C. W. Siemens, Mr. C. W. Merrifield, Dr. Neilson Hancock, Mr. Abel, Captain Douglas Galton, Mr. Newmarch, Mr. E. H. Carbutt, Mr. Macrory, Mr. H. Trueman Wood, Mr. W. H. Barlow, and Mr. A. T. Atchison be reappointed a Committee for the purpose of watching and reporting to the Council on Patent Legislation; that Mr. Bramwell be the Secretary, and that the sum of 5*l*. be placed at their disposal for the purpose.

That a Committee be appointed, consisting of Mr. James Glaisher, Mr. C. W. Merrifield, Mr. F. J. Bramwell, Professor O. Reynolds, Professor W. Cawthorne Unwin, Mr. Rogers Field, and Mr. A. T. Atchison, to consider and report upon the best means of ascertaining the effective Wind Pressures to which buildings and structures are exposed; that Mr. A. T. Atchison be the Secretary, and that the sum of 5*l*. be placed at their disposal for the purpose.

That Professor Osborne Reynolds, Sir William Thomson, Mr. C. W. Merrifield, and Mr. J. T. Bottomley be a Committee for the purpose of continuing the investigation on the Effect of Propellers on the Steering of Steamships; that Professor Osborne Reynolds be the Secretary, and that the sum of 5*l*. be placed at their disposal for the purpose.

Not involving Grants of Money.

That the Committee, consisting of Professor Sir William Thomson, Professor Tait, Dr. C. W. Siemens, Mr. F. J. Bramwell, and Mr. J. T. Bottomley, for continuing secular experiments upon the Elasticity of Wires be reappointed; and that Mr. J. T. Bottomley be the Secretary.

That the Committee, consisting of Mr. David Gill, Professor G. Forbes, Mr. Howard Grubb, and Mr. C. H. Gimingham, be reappointed to consider the question of improvements in Astronomical Clocks; and that Mr. David Gill be the Secretary.

That the Committee, consisting of the Rev. Dr. Haughton and Mr. B. Williamson, for the calculation of Tables of Sun-heat Coefficients be reappointed for the purpose of completing their report; and that Dr. Haughton be the Secretary.

That the Committee, consisting of Professor A. S. Herschel, Professor W. E. Ayrton, Professor P. M. Duncan, Professor G. A. Lebour, Mr. J. T. Dunn, and Professor J. Perry, be reappointed for the purpose of preparing a final report on experiments to determine the Thermal Conductivities of certain Rocks, showing especially the geological aspects of the investigation ; and that Professor A. S. Herschel be the Secretary.

That the Committee, consisting of Professor W. E. Ayrton, Dr. O. J. Lodge, Mr. J. E. H. Gordon, and Mr. J. Perry, be reappointed for the purpose of accurately measuring the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures ; and that Professor W. E. Ayrton be the Secretary.

That Sir William Thomson, Professor Roscoe, Dr. J. H. Gladstone, and Dr. Schuster be a Committee for the purpose of collecting information with regard to Meteoric Dust, and to consider the question of undertaking regular observations in various localities; and that Dr. Schuster be the Secretary.

That the Committee, consisting of Professor G. Forbes, Professor W. G. Adams, and Professor W. E. Ayrton, be reappointed for the purpose of improving an instrument for detecting the presence of Fire-damp in Mines ; and that Professor G. Forbes be the Secretary.

That the Committee, consisting of Captain Abney, Professor W. G. Adams, and Professor G. C. Foster, be reappointed to carry out an investigation for the purpose of fixing a Standard of White Light; and that Captain Abney be the Secretary.

That the Committee, consisting of Mr. Spottiswoode, Professor G. G. Stokes, Professor Cayley, Professor H. J. S. Smith, Professor Sir William Thomson, Professor Henrici, Lord Rayleigh, and Mr. J. W. L. Glaisher, on Mathematical Notation and Printing be reappointed; and that Mr. J. W. L. Glaisher be the Secretary.

That the Committee, consisting of Professor Cayley, Professor F. Fuller, Mr. J. W. L. Glaisher, the Rev. R. Harley, Mr. R. B. Hayward, Professor Henrici, Dr. T. A. Hirst, Mr. C. W. Merrifield, Professor Bartholomew Price, Professor H. J. S. Smith, Mr. W. Spottiswoode, Mr. G. Johnstone Stoney, Professor Townsend, Mr. J. M. Wilson, and Dr. Wormell, be reappointed to consider and report upon the subject of Geometrical Teaching, and particularly upon the Syllabuses prepared under the authority of the Association for the Improvement of Geometrical Teaching; and that Mr. C. W. Merrifield be the Secretary.

That the Committee, consisting of Professor Cayley, Professor G. G. Stokes, Professor H. J. S. Smith, Professor Sir William Thomson, Mr. James Glaisher, and Mr. J. W. L. Glaisher, on Mathematical Tables be reappointed ; and that Mr. J. W. L. Glaisher be the Secretary.

That Mr. W. M. Hicks be requested to prepare a report upon recent Progress in Hydrodynamics.

That the Committee, consisting of Professor G. C. Foster, Professor W. G. Adams, Professor R. B. Clifton, Professor Cayley, Professor J. D. Everett, Lord Rayleigh, Professor G. G. Stokes, Professor Balfour Stewart, Mr. Spottiswoode, and Professor P. G. Tait, be reappointed for the purpose of endeavouring to procure Reports on the progress of the chief branches of Mathematics and Physics; and that Professor G. C. Foster be the Secretary.

That Professors J. Prestwich, T. M'K. Hughes, W. Boyd Dawkins, and T. G. Bonney, the Rev. H. W. Crosskey, Dr. Deane, and Messrs. C. E. De

Rance, G. H. Morton, D. Mackintosh, R. H. Tiddeman, J. E. Lee, James Plant, W. Pengelly, W. Molyneux, H. G. Fordham, and W. Terrill be reappointed a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; and that the Rev. H. W. Crosskey be the Secretary.

That Mr. J. A. Harvie Brown, Mr. J. Cordeaux, and Professor Newton be a Committee for the purpose of obtaining (with the consent of the Master and Brethren of the Trinity House and of the Commissioners of Northern Lights) observations on the Migration of Birds at Lighthouses and Lightships, and of reporting upon the same at York in 1881; and that Mr. Cordeaux be the Secretary.

That Mr. C. Spence Bate and Mr. J. Brooking Rowe be reappointed a Committee for the purpose of completing the Exploration of the Marine Zoology of South Devon; and that Mr. Spence Bate be the Secretary.

That Professor Leone Levi, Mr. Stephen Bourne, Mr. Brittain, Dr. Hancock, Professor Jevons, and Mr. F. P. Fellows be a Committee for the purpose of inquiring into and reporting on the present appropriation of wages and other sources of income, and considering how far it is consonant with the economic progress of the people of the United Kingdom; and that Professor Leone Levi be the Secretary.

That Mr. James Heywood, Mr. Shaen, Mr. Stephen Bourne, Mr. Robert Wilkinson, the Rev. W. Delany, Mr. Maskelyne, M.P., Dr. Sylvanus Thompson, Miss Lydia E. Becker, Mr. E. M. Hance, and Dr. Gladstone, with power to add to their number, be a Committee for the purpose of reporting on the manner in which Rudimentary Science should be taught, and how examinations should be held therein, in Elementary Schools; and that Dr. J. H. Gladstone be the Secretary.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That Professor W. G. Adams's paper, 'On the Comparison of Declination Magnetographs at various places,' be printed *in extenso* in the Report.

That Mr. Whitaker's 'List of Works on the Geology, Mineralogy, and Palæontology of Wales' be printed *in extenso* in the Report.

That Dr. Dobson's paper, on 'Additions to our Knowledge of the Chiroptera,' be printed *in extenso* in the Report.

That the paper by Dr. Gwyn Jeffreys, 'On the French Deep-sea Exploration in the Bay of Biscay,' be printed *in extenso* in the Report.

That the paper by Mr. Stephen Bourne, on 'Recent Revival in Trade,' be printed *in extenso* in the Report.

That the paper by Mr. C. H. Perkins, on 'Anthracite Coal,' be printed *in extenso* in the Report.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Swansea Meeting in August and September 1880. *The Names of the Members who are entitled to call on the General Treasurer for the respective Grants are prefixed.*

A.—*Mathematics and Physics.*

	£	s.	d.
Darwin, Mr. G. H.—Lunar Disturbance of Gravity	30	0	0
Everett, Prof.—Underground Temperature	20	0	0
Foster, Prof. G. Carey.—Electrical Standards	100	0	0
Glaisher, Mr. James—Luminous Meteors	15	0	0
Joule, Dr.—Mechanical Equivalent of Heat	40	0	0
Lodge, Dr. O.—High Insulation Key	5	0	0
Sylvester, Prof.—Fundamental Invariants	40	0	0
Thomson, Sir William.—Seismic Experiments	30	0	0
Thomson, Sir William.—Tidal Observations	10	0	0
Thomson, Mr. J. M.—Inductive Capacity of Crystals and Paraffines	10	0	0

B.—*Chemistry.*

Dewar, Prof.—Spectrum Analysis	10	0	0
Gladstone, Dr.—Specific Refractions	10	0	0

C.—*Geology.*

Duncan, Prof. P. M.—Fossil Polyzoa	10	0	0
Evans, Mr. J.—Geological Record	100	0	0
Hull, Prof. E.—Underground Waters	10	0	0
Ramsay, Prof. A. C.—Earthquakes in Japan	25	0	0
Sorby, Dr.—Metamorphic Rocks	10	0	0
Williamson, Prof. W. C.—Tertiary Flora	20	0	0

D.—*Biology.*

Foster, Dr. M.—Scottish Zoological Station	50	0	0
Foster, Dr. M.—Naples Zoological Station	75	0	0
Godwin-Austen, Lieut.-Col.—Natural History of Socotra	50	0	0
Carried forward	670	0	0

	£	s.	d.
Brought forward	670	0	0
Jeffreys, Mr. J. Gwyn.—Exploration of Sea-bed North of the Hebrides	50	0	0
Pitt-Rivers, General.—Anthropological Notes	20	0	0
Pye-Smith, Dr.—Elimination of Nitrogen during Bodily Exercise	50	0	0
Rolleston, Prof.—Prehistoric Remains in Dorsetshire	25	0	0
Sclater, Mr.—Natural History of Timor-Lant	50	0	0
Stainton, Mr.—Zoological Record	100	0	0

F.—*Economic Science and Statistics.*

Galton, Mr. F.—Estimation of Weights and Heights of Human Beings	30	0	0

G.—*Mechanics.*

Bramwell, Mr.—Patent Laws	5	0	0
Glaisher, Mr. James.—Wind Pressure on Buildings	5	0	0
Reynolds, Prof. Osborne.—Steering of Steamships	5	0	0
	£1010	0	0

The Annual Meeting in 1881.

The Meeting at York will commence on Wednesday, August 31, 1881.

Place of Meeting in 1882.

The Annual Meeting of the Association in 1882 will be held at Southampton.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

	£	s.	d.
1844.			
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8
1845.			
Publications of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9
1846.			
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0
1847.			
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

	£	s.	d.
1848.			
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8
1849.			
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6
1850.			
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

	£	s.	d.
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcon Quarries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Eliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid..............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland......	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record..............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall................	100	0	0
Ohm's Law.......................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate or Ethyl Sodaceto-acetate..........................	5	0	0
Estimation of Potash and Phosphoric Acid...............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record..............	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record..............	100	0	0
Close Time.......................	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station..............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam Vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record..............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on......	20	0	0
Mechanical Equivalent of Heat............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid...............	1	18	0
Geological Record..............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c...............	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record..............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure........................	30	0	0
Calculation of Factor Table of Fourth Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less known Alkaloids..........................	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors...............	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Co-efficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

	£	s.	d.
1880.			
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Co-efficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

General Meetings.

On Wednesday, August 25, at 8 P.M., in the Music Hall, Professor G. J. Allman, M.D., LL.D., F.R.S. L. & E., Pres. L.S., resigned the office of President to Andrew Crombie Ramsay, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology, who took the Chair, and delivered an Address, for which see page 1.

On Thursday, August 26, at 8 P.M., a Soirée took place at the Pavilion, Burrows Square.

On Friday, August 27, at 8.30 P.M., in the Music Hall, Professor W. Boyd Dawkins, M.A., F.R.S., delivered a Discourse on 'Primeval Man.'

On Monday, August 30, at 8.30 P.M., in the Music Hall, Francis Galton, Esq., M.A., F.R.S., delivered a Discourse on 'Mental Imagery.'

On Tuesday, August 31, at 8 P.M., a Soirée took place at the Pavilion, Burrows Square.

On Wednesday, September 1, at 2.30 P.M., the concluding General Meeting took place in the Music Hall, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to York. [The Meeting is appointed to commence on Wednesday, August 31, 1881.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

ANDREW CROMBIE RAMSAY, Esq.,

LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology,

PRESIDENT.

On the Recurrence of Certain Phenomena in Geological Time.

In this address I propose to consider the recurrence of the same kind of incidents throughout all geological time, as exhibited in the various formations and groups of formations that now form the known parts of the external crust of the earth. This kind of investigation has for many years forced itself on my attention, and the method I adopt has not heretofore been attempted in all its branches. In older times, Hutton and Playfair, in a broad and general manner, clearly pointed the way to the doctrine of uniformity of action and results, throughout all known geological epochs down to the present day; but after a time, like the prophets of old, they obtained but slight attention, and were almost forgotten, and the wilder cosmical theories of Werner more generally ruled the opinions of the geologists of the time. Later still, Lyell followed in the steps of Playfair, with all the advantages that the discoveries of William Smith afforded, and aided by the labours of that band of distinguished geologists, Sedgwick, Buckland, Mantell, De la Beche, Murchison, and others, all of whom some of us knew. Notwithstanding this new light, even now there still lingers the relics of the belief (which some of these geologists also maintained), that the physical phenomena which produced the older strata were not only different in kind, but also in degree from those which now rule the external world. Oceans, the waters of which attained a high temperature, attended the formation of the *primitive* crystalline rocks. Volcanic eruptions, with which those of modern times are comparatively insignificant, the sudden upheaval of great mountain chains, the far more rapid decomposition and degradation of rocks, and, as a consequence, the more rapid deposition of strata formed from their waste—all these were assumed as certainties, and still linger in some parts of the world among living geologists of deservedly high reputation. The chief object of this

address is, therefore, to attempt to show, that whatever may have been the state of the world long before geological history began, as now written in the rocks, all known formations are comparatively so recent in geological time, that there is no reason to believe that they were produced under physical circumstances differing either in kind or degree from those with which we are now more or less familiar.

It is unnecessary for my present purpose to enter into details connected with the recurrence of marine formations, since all geologists know that the greater part of the stratified rocks were deposited in the sea, as proved by the molluscs and other fossils which they contain, and the order of their deposition and the occasional stratigraphical breaks in succession are also familiar subjects. What I have partly to deal with now, are exceptions to true marine stratified formations, and after some other important questions have been considered, I shall proceed to discuss the origin of various non-marine deposits from nearly the earliest known time down to what by comparison may almost be termed the present day.

Metamorphism.

All, or nearly all, stratified formations have been in a sense metamorphosed, since, excepting certain limestones, the fact of loose incoherent sediments having been by pressure and other agencies turned into solid rocks constitutes a kind of metamorphism. This, however, is only a first step toward the kind of metamorphism the frequent recurrence of which in geological time I have now to insist upon, and which implies that consolidated strata have undergone subsequent changes of a kind much more remarkable.

Common stratified rocks chiefly consist of marls, shales, slates, sandstones, conglomerates, and limestones, generally distinct and definite; but not infrequently a stratum, or strata, may partake of the characters in varied proportions of two or more of the above-named species. It is from such strata that metamorphic rocks have been produced, exclusive of the metamorphism of igneous rocks, on which I will not enter. These may be looked for in manuals of geology, and sometimes they may be found in them.

As a general rule, metamorphic rocks are apt to be much contorted, not only on a large scale, but also that the individual layers of mica quartz and felspar in gneiss are bent and folded in a great number of minute convolutions, so small that they may be counted by the hundred in a foot or two of rock. Such metamorphic rocks are often associated with masses of granite both in bosses and in interstratified beds or layers, and where the metamorphism becomes extreme it is often impossible to draw a boundary line between the gneiss and the granite; while, on the other hand, it is often impossible to draw any true boundary between gneiss (or other metamorphic rocks) and the ordinary strata that have

partly undergone metamorphism. Under these circumstances, it is not surprising that when chemically analysed, there is often little difference in the constituents of the unmetamorphosed and the metamorphosed rock. This is a point of some importance in relation to the origin and non-primitive character of gneiss and other varieties of foliated strata, and also of some quartzites and crystalline limestones.

I am aware that in North America formations consisting of metamorphic rocks have been stated to exist of older date than the Laurentian gneiss, and under any circumstances it is obvious that vast tracts of pre-Laurentian land must have existed in all regions, by the degradation of which, sediments were derived wherewith to provide materials for the deposition of the originally unaltered Laurentian strata. In England, Wales, and Scotland attempts have also been made to prove the presence of more ancient formations, but I do not consider the data provided sufficient to warrant any such conclusion. In the Highlands of Scotland, and in some of the Western Isles, there are gneissic rocks of pre-Cambrian age, which, since they were first described by Sir Roderick Murchison in the North-west Highlands, have been, I think justly, considered to belong to the Laurentian series, unconformably underlying Cambrian and Lower Silurian rocks, and as yet there are no sufficient grounds for dissenting from his conclusion that they form the oldest known rocks in the British Islands.

It is unnecessary here to discuss the theory of the causes that produced the metamorphism of stratified rocks, and it may be sufficient to say, that under the influence of deep underground heat, aided by moisture, sandstones have been converted into quartzites, limestones have become crystalline, and in shaley, slaty, and schistose rocks, under like circumstances, there is little or no development of new material, but rather, in the main, a re-arrangement of constituents according to their chemical affinities in rudely crystalline layers, which have very often been more or less developed in pre-existing planes of bedding. The materials of the whole are approximately the same as those of the unaltered rock, but have been re-arranged in layers, for example, of quartz, felspar, and mica, or of hornblende, &c., while other minerals, such as schorl and garnets, are of not infrequent occurrence.

It has for years been an established fact that nearly the whole of the mountain masses of the Highlands of Scotland (exclusive of the Laurentian, Cambrian, and Old Red Sandstone formations), mostly consist of gneissic rocks of many varieties, and of quartzites and a few bands of crystalline limestone, which, from the north shore to the edge of the Old Red Sandstone, are repeated again and again in stratigraphical convolutions great and small. Many large bosses, veins, and dykes of granite are associated with these rocks, and, as already stated, it sometimes happens that it is hard to draw a geological line between granite and gneiss and *vice versâ*. These rocks, once called Primary or Primitive, were first proved by Sir Roderick Murchison to be of Lower Silurian age, thus revolu-

tionising the geology of nearly one-half of Scotland. To the same age belongs by far the greater part of the broad hilly region of the south of Scotland that lies between St. Abb's Head on the east and the coast of Ayrshire and Wigtonshire on the west. In the south-west part of this district, several great masses of granite rise amid the Lower Silurian rocks, which in their neighbourhood pass into mica-schist and even into fine-grained gneiss.

In Cornwall the occurrence of Silurian rocks is now well known. They are of metamorphic character, and partly associated with granite; and at Start Point, in South Devonshire, the Silurian strata have been metamorphosed into quartzites.

In parts of the Cambrian areas, Silurian rocks in contact with granite have been changed into crystalline hornblendic gneiss, and in Anglesey there are large tracts of presumed Cambrian strata, great part of which have been metamorphosed into chlorite and mica-schist and gneiss, and the same is partly the case with the Lower Silurian rocks of the centre of the island, where it is almost impossible to disentangle them from the associated granite.

In Ireland similar metamorphic rocks are common, and, on the authority of Prof. Hull, who knows them well, the following statements are founded :—'Metamorphism in Ireland has been geographical and not stratigraphical, and seems to have ceased before the Upper Silurian period.

'The epoch of greatest metamorphism appears to have been that which intervened between the close of the Lower Silurian period and the commencement of the Upper Silurian, taking the formations in ascending order.

'It is as yet undecided whether Laurentian rocks occur in Ireland. There are rocks in north-west Mayo very like those in Sutherlandshire, but if they are of Laurentian age they come directly under the metamorphosed Lower Silurian rocks, and it may be very difficult to separate them.

'Cambrian purple and green grits are not metamorphosed in the counties of Wicklow and Dublin, but the same beds at the southern extremity of County Wexford, near Carnsore Point, have been metamorphosed into mica-schist and gneiss.

'In the east of Ireland the Lower Silurian grits and slates have not been metamorphosed, except where in proximity to granite, into which they insensibly pass in the counties of Wicklow, Dublin, Westmeath, Cavan, Longford, and Down; but in the west and north-west of Ireland they have been metamorphosed into several varieties of schists, hornblende-rock, *and gniess, or foliated granite.*'

It would be easy to multiply cases of the metamorphism of Silurian rocks on the continent of Europe, as, for example, in Scandinavia, and in the Ural Mountains, where, according to Murchison, 'by following its masses upon their strike, we are assured that the same zone which in one

tract has a mechanical aspect and is fossiliferous, graduates in another parallel of latitude into a metamorphic crystalline condition, whereby not only the organic remains, but even the original impress of sedimentary origin are to a great degree obliterated.' The same kind of phenomena are common in Canada and the United States; and Medlicott and Blanford, in 'The Geology of India,' have described the thorough metamorphism of Lower Silurian strata into gneiss and syenitic and hornblende schists.

In Britain, none of the Upper Silurian rocks have undergone any serious change beyond that of ordinary consolidation, but in the Eastern Alps at Gratz, Sir Roderick Murchison has described both Upper Silurian and Devonian strata interstratified with separate courses of metamorphic chloritic schist.

Enough has now been said to prove the frequent occurrence of metamorphic action among Cambrian and Lower and Upper Silurian strata.

If we now turn to the Devonian and Old Red Sandstone strata of England and Scotland, we find that metamorphic action has also been at work, but in a much smaller degree. In Cornwall and Devon, five great bosses of granite stand out amid the stratified Silurian, Devonian, and Carboniferous formations. Adjoining or near these bosses the late Sir Henry De la Beche remarks, that 'in numerous localities we find the coarser slates converted into rocks resembling mica-slate and gneiss, a fact particularly well exhibited in the neighbourhood of Meavy, on the south-east of Tavistock,' and 'near Camelford we observed a fine arenaceous and micaceous grauwacke turned into a rock resembling mica-slate near the granite.' Other cases are given by the same author, of slaty strata turned into mica-schist and gneiss in rocks now generally considered to be of Devonian age.

The Devonian rocks and Old Red Sandstone are of the same geological age, though they were deposited under different conditions, the first being of marine, and the latter of fresh-water, origin. The Old Red Sandstone of Wales, England, and Scotland has not, as far as I know, suffered any metamorphism, excepting in one case in the north-east of Ayrshire, near the sources of the Avon Water, where a large boss of granite rises through the sandstone, which all round has been rendered crystalline with well-developed crystals of felspar.

On the continent of Europe, a broad area of Devonian strata lies on both banks of the Rhine and the Moselle. Forty years ago, Sedgwick and Murchison described the crystalline quartzites, chlorite, and micaceous slates of the Hundsruck and the Taunus, and from personal observation I know that the rocks in the country on either side of the Moselle are, in places, of a foliated or semi-foliated metamorphic character. In the Alps also, as already noticed, metamorphic Devonian strata occur interstratified with beds of metamorphic schists, and, Sir Roderick adds, 'we have ample data to affirm, that large portions of the Eastern Alps . . . are

occupied by rocks of true palæozoic age, which in many parts have passed into a crystalline state.'

I know of no case in Britain where the Carboniferous strata have been thoroughly metamorphosed, excepting that in South Wales, beds of coal, in the west of Caermarthenshire and in South Pembrokeshire, gradually pass from so-called bituminous coal into anthracite. The same is the case in the United States, in both instances the Carboniferous strata being exceedingly disturbed and contorted. In the Alps, however, Sir Roderick Murchison seems to have believed that Carboniferous rocks may have been metamorphosed: a circumstance since undoubtedly proved by the occurrence of a coal-measure calamite, well preserved, but otherwise partaking of the thoroughly crystalline character of the gneiss in which it is imbedded, and which was shown to me by the late Prof. Gastaldi, at Turin.

I am well acquainted with all the Permian strata of the British Islands and of various parts of continental Europe, and nowhere, that I have seen, have they suffered from metamorphic action, and strata of this age are, I believe, as yet unknown in the Alps. This closes the list of metamorphism of palæozoic strata.

I will not attempt (they are so numerous) to mention all the regions of the world in which Mesozoic or Secondary formations have undergone metamorphic action. In Britain and the non-mountainous parts of France, they are generally quite unaltered, but in the Alps it is different. There, as everyone knows who is familiar with that region, the crystalline rocks in the middle of the chain have the same general strike as the various flanking stratified formations. As expressed by Murchison, 'as we follow the chain from N.E. to S.W. we pass from the clearest types of sedimentary rocks, and, at length, in the Savoy Alps, are immersed in the highly altered mountains of Secondary limestone,' while 'the metamorphism of the rocks is greatest as we approach the centre of the chain,' and, indeed, any one familiar with the Alps of Switzerland and Savoy knows that a process of metamorphism has been undergone *by all the Jurassic rocks* (Lias and Oolites) of the great mountain chain. Whether or not any strata of Neocomian and Cretaceous age have been well metamorphosed in this region I am unable to say; but it seems to be certain that the Eocene or Lower Tertiary Alpine formation, known as the Flysch, contains beds of black schists which pass into Lydian stone, and also that in the Grisons it has been converted into gneiss and mica-schist, a fact mentioned by Studer and Murchison. I also have seen in the country north of the Oldenhorn, nummulitic rocks so far foliated that they formed an imperfect gneiss.

In Tierra del Fuego, as described by Darwin, clay slates of early cretaceous date pass into gneiss and mica-slate with garnets, and in Chonos Islands, and all along the great Cordillera of the Andes of Chili, rocks of Cretaceous or Cretaceo-oolitic age have been metamorphosed into foliated mica-slate and gneiss, accompanied by the presence of granite, syenite, and greenstone.

This ends my list, for I have never seen, or heard, of metamorphic rocks of later date than those that belong to the Eocene series. Enough, however, has been said to prove, that from the Laurentian epoch onward, the phenomenon of extreme metamorphism of strata has been of frequent recurrence all through Palæozoic and Mesozoic times, and extends even to a part of the Eocene series equivalent to the soft unaltered strata of the formations of the London and Paris basins, which excepting for their fossil contents, and sometimes highly inclined positions, look as if they had only been recently deposited.

Volcanoes.

The oldest volcanic products of which I have personal knowledge are of Lower Silurian age. These in North Wales consist of two distinct series, the oldest of which, chiefly formed of felspathic lavas and volcanic ashes, lie in and near the base of the Llandeilo beds, and the second, after a long interval of repose, were ejected and intermingled with the strata forming the middle part of the Bala beds. The Lower Silurian rocks of Montgomeryshire, Shropshire, Radnorshire, Pembrokeshire, Cumberland and Westmoreland are to a great extent also the result of volcanic eruptions, and the same kinds of volcanic rocks occur in the Lower Silurian strata of Ireland. I know of no true volcanic rocks in the Upper Silurian series.

In the old Red Sandstone of Scotland lavas and volcanic ashes are of frequent occurrence, interstratified with the ordinary lacustrine sedimentary strata. Volcanic rocks are also intercalated among the Devonian strata of Devonshire. I know of none in America or on the Continent of Europe.

In Scotland volcanic products are common throughout nearly the whole of the Carboniferous sub-formations, and they are found also associated with Permian strata.

I now come to the Mesozoic or Secondary epochs. Of Jurassic age (Lias and Oolites), it is stated by Lyell with some doubt, that true volcanic products occur in the Morea and also in the Apennines, and it seems probable, as stated by Medlicott and Blanford, that the Rajmahal traps may also be of Jurassic age.

In the Cordillera of South America, Darwin has described a great series of volcanic rocks intercalated among the Cretaceo-oolitic strata that forms so much of the chain; and the same author in his 'Geological Observations in South America,' states that the Cordillera has been, probably with some quiescent periods, a source of volcanic matter from an epoch anterior to his Cretaceo-oolitic formation to the present day. In the Deccan volcanic traps rest on Cretaceous beds, and are overlaid by Nummulitic strata, and according to Medlicott and Blanford, these were poured out in the interval between Middle Cretaceous and Lower Eocene times.

In Europe the only instance I know of a volcano of Eocene age is

that of Monte Bolca near Verona, where the volcanic products are associated with the fissile limestone of that area.

The well-preserved relics of Miocene volcanoes are prevalent over many parts of Europe, such as Auvergne and The Velay, where the volcanic action began in Lower Miocene times, and was continued into the Pliocene epoch. The volcanoes of the Eifel are also of the same general age, together with the ancient Miocene volcanoes of Hungary.

The volcanic rocks of the Azores, Canaries, and Madeira are of Miocene age, while in Tuscany there are extinct volcanoes that began in late Miocene, and lasted into times contemporaneous with the English Coralline Crag. In the north of Spain also, at Olot in Catalonia, there are perfect craters and cones remaining of volcanoes that began to act in newer Pliocene times and continued in action to a later geological date. To these I must add the great *coulées* of Miocene lava, so well known in the Inner Hebrides, on the mainland near Oban, &c., in Antrim in the north of Ireland, in the Faroe Islands, Greenland, and Franz-Joseph Land. It is needless, and would be tiresome, further to multiply instances, for enough has been said to show that in nearly all geological ages volcanoes have played an important part, now in one region, now in another, from very early Palæozoic times down to the present day; and, as far as my knowledge extends, at no period of geological history is there any sign of their having played a more important part than they do in the epoch in which we live.

Mountain Chains.

The mountain-chains of the world are of different geological ages, some of them of great antiquity, and some of them comparatively modern.

It is well known that in North America the Lower Silurian rocks lie uncomformably on the Laurentian strata, and also that the latter had undergone a thorough metamorphism and been thrown into great anticlinal and synclinal folds, accompanied by intense minor convolutions, before the deposition of the oldest Silurian formation, that of the Potsdam Sandstone. Disturbances of the nature alluded to imply beyond a doubt that the Laurentian rocks formed a mountain chain of pre-Silurian date, which has since constantly been worn away and degraded by sub-aerial denudation.

In Shropshire, and in parts of North Wales, and in Cumberland and Westmoreland, the Lower Silurian rocks by upheaval formed hilly land before the beginning of the Upper Silurian epoch; and it is probable that the Lower Silurian gneiss of Scotland formed mountains at the same time, probably very much higher than now. However that may be, it is certain, that these mountains formed high land before and during the deposition of the Old Red Sandstone, and the upheaval of the great Scandinavian chain (of which the Highlands may be said to form an out-

lying portion) also preceded the deposition of the Old Red Strata. In both of these mountain regions the rocks have since undergone considerable movements, which in the main seem to have been movements of elevation, accompanied undoubtedly by that constant atmospheric degradation to which all high land is especially subject.

The next great European chain in point of age is that of the Ural, which according to Murchison is of pre-Permian age, a fact proved by the Permian conglomerates which were formed from the waste of the older strata. On these they lie quite unconformably and nearly undisturbed on the western flank of the mountains.

In North America the great chain of the Alleghany Mountains underwent several disturbances, the last (a great one) having taken place after the deposition of the Carboniferous rocks, and before that of the New Red Sandstone. The vast mountainous region included under the name of the Rocky Mountains, after several successive disturbances of upheaval, did not attain its present development till after the Miocene or Middle Tertiary epoch.

In South America, notwithstanding many oscillations of level recorded by Darwin, the main great disturbance of the strata that form the chain of the Andes took place apparently *in post-cretaceous times.*

The Alps, the rudiments of which began in more ancient times, received their greatest disturbance and upheaval in post-Eocene days, and were again raised at least 5,000 feet (I believe much more) at the close of the Miocene epoch. The Apennines, the Pyrenees, the Carpathians, and the great mountain region on the east of the Adriatic and southward into Greece, are of the same general age, and this is also the case in regard to the Atlas in North Africa, and the Caucasus on the borders of Europe and Asia. In the north of India the history of the Great Himalayan range closely coincides with that of the Alps, for while the most powerful known disturbance and elevation of the range took place after the close of the Eocene epoch, a subsequent elevation occurred in post-Miocene times closely resembling and at least equal to that sustained by the Alps at the same period.

It would probably not be difficult by help of extra research to add other cases to this notice of recurrences of the upheaval and origin of special mountain chains, some of which I have spoken of from personal knowledge; but enough has been given to show the bearing of this question on the argument I have in view, namely, that of repetition of the same kind of events throughout all known geological time.

Salt and Salt Lakes.

I now come to the discussion of the circumstances that produced numerous recurrences of the development of beds of various salts (chiefly common rock-salt) in many formations, which it will be seen are to a great extent connected with continental or inland conditions. In com-

paratively rainless countries salts are often deposited on the surface of the ground by the effect of solar evaporation of moisture from the soil. Water dissolves certain salts in combination with the ingredients of the underlying rocks and soils, and brings it to the surface, and when solar evaporation ensues the salt or salts are deposited on the ground. This is well known to be the case in and near the region of the Great Salt Lake in North America, and in South America in some of the nearly rainless districts of the Cordillera, extensive surface-deposits of salts of various kinds are common. The surface of the ground around the Dead Sea is also in extra dry seasons covered with salt, the result of evaporation, and in the upper provinces of India (mentioned by Medlicott and Blanford) 'many tracts of land in the Indo-Gangetic alluvial plain are rendered worthless for cultivation by an efflorescence of salt known in the North-West Provinces as *Reh*,' while every geographer knows that in Central Asia, from the western shore of the Caspian Sea to the Kinshan Mountains of Mongolia, with rare exceptions nearly every lake is salt in an area at least 3,500 miles in length. This circumstance is due to the fact that all so-called fresh-water springs, and therefore all rivers, contain small quantities of salts in solution only appreciable to the chemist, and by the constant evaporation of pure water from the lakes, in the course of time, it necessarily happens that these salts get concentrated in the water by the effect of solar heat, and, if not already begun, precipitation of solid salts must ensue.

The earliest deposits of rock-salt that I know about have been described by Mr. A. B. Wynne of the Geological Survey of India, in his Memoir 'On the Geology of the Salt Range in the Punjab.'[1] The beds of salt are of great thickness, and along with gypsum and dolomitic layers occur in marl of a *red colour* like our Keuper Marl. This colour I have for many years considered to be, in certain cases, apt to indicate deposition of sediments in inland lakes, salt or fresh, as the case may be, and with respect to these strata in the Punjab Salt Range, authors seem to be in doubt whether they were formed in inland lakes or in lagoons near the seaboard, which at intervals were liable to be flooded by the sea, and in which in the hot seasons salts were deposited by evaporation caused by solar heat. For my argument, it matters but little which of these was the true physical condition of the land of the time, though I incline to think the inland lake theory most probable. The age of the strata associated with this salt is not yet certainly ascertained. In 'The Geology of India' Medlicott and Blanford incline to consider them of Lower Silurian age, and Mr. Wynne, in his 'Geology of the Salt Range,' places the salt and gypsum beds doubtfully on the same geological horizon.

The next salt-bearing formation that I shall notice is the Salina or Onondaga Salt Group of North America, which forms part of the Upper Silurian rocks, and lies immediately above the Niagara Limestone. It is rich in gypsum and in salt-brine, often of a very concentrated character,

[1] Many earlier notices and descriptions of the Salt Range might be quoted, but Mr. Wynne's is enough for my purpose.

'which can only be derived from original depositions of salt,' and it is also supposed by Dr. T. Sterry Hunt to contain solid rock-salt 115 feet in thickness at the depth of 2,085 feet, near Saginaw Bay in Michigan.

In the Lower Devonian strata of Russia near Lake Ilmen, Sir R. Murchison describes salt springs at Starai Russa. Sinkings 'made in the hope of penetrating to the source of these salt springs,' reached a depth of 600 feet without the discovery of rock salt, 'and we are left in doubt whether the real source of the salt is in the lowest beds of the Devonian rocks or even in the Silurian system.'

In the United States brine springs also occur in Ohio, Pennsylvania, and Virginia, in Devonian rocks.

In Michigan salts are found from the Carboniferous down to the Devonian series; and in other parts of the United States, Western Pennsylvania, Virginia, Ohio, Illinois, and Kentucky, from the lower Coal-measures salts are derived which must have been deposited in inland areas, since even in the depths of inland seas that communicate with the great ocean, such as the Mediterranean and the Red Sea, no great beds of salt can be deposited. Before such strata of salt can be formed, super-saturation must have taken place.

In the North of England at and near Middlesbrough two deep bore-holes were made some years ago in the hope of reaching the Coal-measures of the Durham coal-field. One of them at Salthome was sunk to a depth of 1,355 feet. First they passed through 74 feet of superficial clay and gravel, next through about 1,175 feet of red sandstones and marls, with beds of rock-salt and gypsum. The whole of these strata (excepting the clay and gravel) evidently belong to the Keuper marls and sandstones of the upper part of our New Red series. Beneath these they passed through 67 feet of dolomitic limestone, which in this neighbourhood forms the upper part of the Permian series, and beneath the limestone the strata consist of 27 feet of gypsum and rock-salt and marls, one of the beds of rock-salt having a thickness of 14 feet. This bed of Permian salt is of some importance, since I have been convinced for long that the British Permian strata were deposited, not in the sea, but in salt lakes comparable in some respects to the great salt lake of Utah, and in its restricted fauna to the far greater salt lake of the Caspian Sea. The gypsum, the dolomite or magnesian limestone, the red marls covered with rain-pittings, the sun-cracks, and the impressions of footprints of reptiles made in the soft sandy marls when the water was temporarily lowered by the solar evaporation of successive summers, all point to the fact that our Permian strata were not deposited in the sea, but in a salt lake or lakes once for a time connected with the sea. The same may be said of other Permian areas in the central parts of the Continent of Europe, such as Stassfurt and Anhalt, Halle and Altern in Thuringia, and Sperenberg, near Berlin, and also in India.[1]

[1] See 'Physical Geology and Geography of Great Britain,' 5th edition, where the question is treated in more detail.

Neither do I think that the Permian strata of Russia, as described by Sir Roderick Murchison, were necessarily, as he implies, deposited in a wide ocean. According to his view all marine life universally declined to a minimum after the close of the Carboniferous period, that decline beginning with the Permian and ending with the Triassic epoch. Those who believe in the doctrine of evolution will find it hard to accept the idea which this implies, namely, that all the prolific forms of the Jurassic series sprang from the scanty faunas of the Permian and Triassic epochs. On the contrary, it seems to me more rational to attribute the poverty of the faunas of these epochs to accidental abnormal conditions in certain areas, that for a time partially disappeared during the deposition of the continental Muschelkalk which is absent in the British Triassic series.

In the whole of the Russian Permian strata only fifty-three species were known at the time of the publication of 'Russia and the Ural Mountains,' and I have not heard that this scanty list has been subsequently increased. I am therefore inclined to believe that these red marls, grits, sandstones, conglomerates, and great masses of gypsum and rock-salt were all formed in a flat inland area which was occasionally liable to be invaded by the sea during intermittent intervals of minor depression, sometimes in one area, sometimes in another, and the fauna small in size and poor in numbers is one of the results, while the deposition of beds of salt and gypsum is another. If so, then in the area now called Russia, in sheets of inland Permian water, deposits were formed strictly analogous to those of Central Europe and of Britain, but on a larger scale.

Other deposits of salt deep beneath overlying younger strata are stated to occur at Bromberg in Prussia, and many more might be named as lying in the same formation in northern Germany.

If we now turn to the Triassic series it is known that it consists of only two chief members in Britain, the Bunter Sandstones and the Keuper or New Red Marls, the Muschelkalk of the Continent being absent in our islands. No salt is found in the Bunter sandstones of England, but it occurs in these strata at Schöningen in Brunswick and also near Hanover. In the lower part of the Keuper series deposits of rock-salt are common in England and Ireland. At Almersleben, near Calbe, rock-salt is found in the Muschelkalk, and also at Erfurt and Slottenheim in Thuringia and at Wilhelmsglück in Wurtemburg. In other Triassic areas it is known at Honigsen, in Hanover, in middle Keuper beds. In the red shales at Sperenberg and Lieth on the Lower Elbe, salt was found at the depth of 3,000 feet, and at Stassfurth the salt is said to be 'several hundred yards thick.'

In Central Spain rock-salt is known, and at Tarragona, Taen, and also at Santander in the north of Spain, all in Triassic strata. Other localities may be named in the Upper Trias, such as the Salzkammergut, Aussee, Hallstatt, Ischl, Hallein in Salzburg, Halle in the Tyrol, and Berchesgaden in Bavaria.

In the Salt Range of mountains in Northern India saliferous strata are referred with some doubt by Medlicott and Blanford to the Triassic strata.

In the Jurassic series (Lias and Oolites) salt and gypsum are not uncommon. One well-known instance occurs at Berg in the valley of the Rhone in Switzerland, where salt is derived from the Lias. Salt and gypsum are also found in Jurassic rocks at Burgos in Spain. At Gap in France there is gypsum, and salt is found in the Austrian Alps in Oolitic limestone.

In the Cretaceous rocks salt occurs, according to Lartet, at Jebel Usdom by the Dead Sea, and other authorities state that it occurs in the Pyrenees and at Biskra in Africa, where 'mountains of salt' are mentioned as of Cretaceous age. The two last-named localities are possibly uncertain; but whether or not this is the case, it is not the less certain that salt has been deposited in Cretaceous rocks, and, judging by analogy, probably in inland areas of that epoch.

In the Eocene or Older Tertiary formations, rock-salt is found at Cardona in Spain, and at Kohat in the Punjab it occurs at the base of Nummulitic beds. It is also known at Mandi in India in strata supposed to be of Nummulitic Eocene age.

The record does not end here, for a zone of rock-salt lies in Sicily at the top of the Salina clays in Lower Miocene beds, and in Miocene strata gypsum is found at several places in Spain, while salt also occurs in beds that are doubtfully of Miocene age (but may be later) at Wielitzka in Poland, Kalusz in Galicia, Bukowina, and also in Transylvania.

In Pliocene or Later Tertiary formations, thick beds of gypsum are known in Zante, and strata of salt occur in Roumania and Galicia, while in Pliocene rocks, according to Dana, or in Post-Tertiary beds, according to others, a thick bed of pure salt was penetrated to a depth of 38 feet at Petit Anse in Louisiana. This ends my list, though I have no doubt that, by further research, many more localities might be given. Enough, however, has been done to show that rock-salt (and other salts) are of frequent *recurrence* throughout all geological time, and as in my opinion it is impossible that common salt can be deposited in the open ocean, it follows that this and other salts must have been precipitated from solutions, which, by the effect of solar evaporation became at length supersaturated, like those of the Dead Sea, the great salt lake of Utah, and in other places which it is superfluous to name.

Fresh-water. Lakes and Estuaries.

I now come to the subject of recurrences of fresh-water conditions both in lakes and estuaries. In the introduction to the 'Geology of India' by Messrs. Medlicott and Blanford, mention is made of the Blaini and Krol rocks as probably occupying 'hollows formed by denudation in the old gneissic rocks,' and the inference is drawn that 'if this be a correct view,

it is probable that the cis-Himalayan palæozoic rocks are in great part of fresh-water origin, and that the present crystalline axis of the Western Himalayas approximately coincides with the shore of the ancient palæozoic continent, of which the Indian peninsula formed a portion.' The Krol rocks are classed broadly with 'Permian and Carboniferous' deposits, but the Blaini beds are doubtfully considered to belong to Upper Silurian strata. If this point be by-and-by established, this is the earliest known occurrence of fresh-water strata in any of the more ancient palæozoic formations.

It is a fact worthy of notice that the colour of the strata formed in old lakes (whether fresh or salt) of palæozoic and mesozoic age is apt to be red: a circumstance due to the fact that each little grain of sand or mud is usually coated with a very thin pellicle of peroxide of iron. Whether or not the red and purple Cambrian rocks [1] may not be *partly* of fresh-water origin, is a question that I think no one but myself has raised.[2]

There is, however, in my opinion, no doubt with regard to the fresh-water origin of the Old Red Sandstone, as distinct from the contemporaneous marine deposits of the Devonian strata. This idea was first started by that distinguished geologist, Doctor Fleming, of Edinburgh, followed by Mr. Godwin-Austen, who, from the absence of marine shells and the nature of the fossil fishes in these strata, inferred that they were deposited, not in the sea, as had always been asserted, but in a great fresh-water lake or in a series of lakes. In this opinion I have for many years agreed, for the nearest analogies of the fish are, according to Huxley, the Polypterus of African rivers, the Ceratodus of Australia, and in less degree the Lepidosteus of North America. The truth of the supposition that the Old Red Sandstone was deposited in fresh water, is further borne out by the occurrence of a fresh-water shell, *Anodonta Jukesii*, and of ferns in the Upper Old Red Sandstone in Ireland; and the same shell is found at Dura Den in Scotland, while in Caithness, along with numerous fishes, there occurs the small bivalve crustacean Estheria Murchisoniæ.

I think it more than probable that the red series of rocks that form the Catskill Mountains of North America, (and with which I am personally acquainted) were formed in the same manner as the Old Red Sandstones of Britain; for excepting in one or two minor interstratifications, they contain no relics of marine life, while 'the fossil fishes of the Catskill beds, according to Dr. Newberry, appear to represent closely those of the British Old Red Sandstone.' (Dana.)

The Devonian rocks of Russia, according to the late Sir Roderick Murchison, consist of two distinct types, viz. Devonian strata identical in general character with those in Devonshire and in various parts of the

[1] By Cambrian, I mean only the *red and purple* rocks of Wales, England, Scotland, and Ireland, older than the Menevian beds, or any later division of the Silurian strata, that may chance to rest upon them.

[2] 'On the Red Rocks of England of older date than the Trias.' *Jour. Geol. Soc.* 1871, vol. 28.

continent of Europe. These are exclusively of a marine character, while the remainder corresponds to the Old Red Sandstone of Wales, England, and Scotland.

At Tchudora, about 105 miles S.E. of St. Petersburg, the lowest members of the series consist of flag-like compact limestones accumulated in a tranquil sea and containing fucoids and encrinites, together with shells of Devonian age, such as Spirifers, Terebratulæ, Orthis, Leptænas, Avicula, Modiola, Natica, Bellerophon, &c., while the upper division graduates into the Carboniferous series as it often does in Britain, and, like the Old Red Sandstone of Scotland, contains only fish-remains, and in both countries they are of the same species. 'Proceeding from the Valdai Hills on the north,' the geologist 'quits *a Devonian Zone with a true "Old Red" type* dipping under the Carboniferous rocks of Moscow, and having passed through the latter, he finds himself suddenly in a yellow-coloured region, entirely dissimilar in structure to what he had seen in any of the northern governments, which, of a different type as regards fossils, is the true stratigraphical *equivalent of the Old Red system.*' This seems to me, as regards the Russian strata, to mean, that just as the Devonian strata of Devonshire are the true equivalents of the Old Red Sandstone of Wales and Scotland, they were deposited under very different conditions, the first in the sea and the others in inland fresh-water lakes. At the time Sir Roderick Murchison's work was completed, the almost universal opinion was that the Old Red Sandstone was a marine formation. In the year 1830, the Rev. Dr. Fleming, of Edinburgh, read a paper before the Wernerian Society in which he boldly stated that the '*Old Red Sandstone* is a *fresh-water formation*' of older date than the Carboniferous Limestone. This statement, however, seems to have made no impression on geologists till it was revived by Godwin-Austen in a memoir 'On the Extension of the Coal-measures,' &c., in the Journal of the Geological Society, 1856. Even this made no converts to what was then considered a heretical opinion. I have long held Dr. Fleming's view, and unfortunately published it in the third edition of 'The Physical Geology and Geography of Great Britain,' without at the time being aware that I had been forestalled by Dr. Fleming and Mr. Godwin-Austen.

To give anything like a detailed account of all the fresh-water formations deposited in estuaries and lakes from the close of the Old Red Sandstone times down to late Tertiary epochs, is only fitted for a manual of geology, and would too much expand this address; and I will therefore give little more than a catalogue of these deposits in ascending order.

In the Coal-measure parts of the Carboniferous series, a great proportion of the shales and sandstones are of fresh-water origin. This is proved all over the British Islands by the shells they contain, while here and there marine interstratifications occur, generally of no great thickness. There is no doubt among geologists that these Coal-measure strata were chiefly

deposited under estuarine conditions, and sometimes in lagoons or in lakes; while numerous beds of coal formed by the life and death of land plants, each underlaid by the soil on which the plants grew, evince the constant recurrence of terrestrial conditions. The same kind of phenomena are characteristic of the Coal-measures all through North America, and in every country on the continent of Europe, from France and Spain on the west, to Russia in the east, and the same is the case in China and in other areas.

In Scotland, according to Prof. Judd, fresh-water conditions occur more or less all through the Jurassic series, from the Lias to the Upper Oolites. In England, fresh-water strata, with thin beds of coal, are found in the Inferior Oolite of Yorkshire, and in the middle of England and elsewhere in the Great Oolite. The Purbeck and Wealden strata, which, in a sense, fill the interval between the Jurassic and Cretaceous series, are almost entirely formed of fresh-water strata, with occasional thin marine interstratifications. By some the Wealden beds are considered to have been formed in and near the estuary of a great river, while others, with as good a show of reason, believe them to have been deposited in a large lake subject to the occasional influx of the sea.

In the eastern part of South Russia the Lias consists chiefly of fresh-water strata, as stated by Neumayr.

The Godwana rocks of Central India range from Upper Palæozoic times well into the Jurassic strata, and there all these formations are of fresh-water origin. Fresh-water beds with shells are also interstratified with the Deccan traps of Cretaceous and Tertiary (Eocene) age, while 2,000 feet of fresh-water sands overlie them.

In South-western Sweden, as stated by Mr. Bauerman, 'the three coal-fields of Hoganas, Stabbarp, and Rodingé, lie in the uppermost Triassic or Rhætic series.' In Africa, the Karoo beds, which it is surmised may be of the age of the New Red Sandstone, contain beds of coal. In North America, certain fresh-water strata, with beds of lignite, apparently belong to the Cretaceous and Eocene epochs, and in the north of Spain and south of France, there are fresh-water lacustrine formations in the highest Cretaceous strata.

In England the lower and upper Eocene strata are chiefly of fresh-water origin, and the same is the case in France and other parts of the Continent. Certain fresh-water formations in Central Spain extend from the Eocene to the upper Miocene strata.

There is only one small patch of Miocene beds in England, at Bovey Tracey, near Dartmoor, formed of fresh-water deposits with interstratified beds of lignite or Miocene coal. On the continent of Europe, Miocene strata occupy immense independent areas, extending from France and Spain to the Black Sea. In places too numerous to name, they contain beds of 'brown coal,' as lignite is sometimes called. These coal-beds are often of great thickness and solidity. In one of the pits which I descended near Teplitz, in Bohemia, the coal, which lies in a true basin,

is 40 feet thick, and underneath it there is a bed of clay, with rootlets, quite comparable to the underclay which is found beneath almost every bed of coal in the British and other coal-fields of the Carboniferous epoch. The Miocene rocks of Switzerland are familiar to all geologists, who have traversed the country between the Jura and the Alps. Sometimes they are soft and incoherent, sometimes formed of sandstones, and sometimes of conglomerates, as on the Righi. They chiefly consist of fresh-water lacustrine strata, with some minor marine interstratifications which mark the influx of the sea during occasional partial submergences of portions of the area. These fresh-water strata, of great extent and thickness, contain beds of lignite, and are remarkable for the relics of numerous trees and other plants which have been described by Prof. Heer of Zurich, with his accustomed skill. The Miocene fresh-water strata, of the Sewalik Hills in India are well known to most students of geology, and I have already stated that they bear the same relation to the more ancient Himalayan mountains that the Miocene strata of Switzerland and the North of Italy do to the pre-existing range of the Alps. In fact, it may be safely inferred that something far more than the rudiments of our present continents existed long before Miocene times, and this accounts for the large areas on those continents which are frequently occupied by Miocene fresh-water strata. With the marine formations of Miocene age this address is in no way concerned, nor is it essential to my argument to deal with those later tertiary phenomena, which in their upper stages so easily merge into the existing state of the world.

Glacial Phenomena.

I now come to the last special subject for discussion in this address, viz., the Recurrence of Glacial Epochs, a subject still considered by some to be heretical, and which was generally looked upon as an absurd crotchet when, in 1855, I first described to the Geological Society, boulder-beds, containing ice-scratched stones, and erratic blocks in the Permian strata of England. The same idea I afterwards applied to some of the Old Red Sandstone conglomerates, and of late years it has become so familiar, that the effects of glaciers have at length been noted by geologists from older Palæzoic epochs down to the present day.

In the middle of last July I received a letter from Prof. Geikie, in which he informed me that he had discovered mammilated *moutonnée* surfaces of Laurentian rocks, passing underneath the Cambrian sandstones of the north-west of Scotland at intervals, all the way from Cape Wrath to Loch Torridon, for a distance of about 90 miles. The mammilated rocks are, says Prof. Geikie, '*as well rounded off as any recent roche moutonnée*,' and, 'in one place these bosses are covered by a huge angular breccia of this old gneiss (Laurentian) with blocks sometimes five or six feet long.' This breccia, where it occurs, forms the base of the Cambrian strata of Sutherland, Ross, and Cromarty, and while the higher strata are

always well stratified, where they approach the underlying Laurentian gneiss 'they become pebbly, passing into coarse unstratified agglomerates or boulder-beds.' In the Gairloch district 'it is utterly unstratified, the angular fragments standing on end and at all angles,' just as they do in many modern moraine mounds wherever large glaciers are found. The general subject of Palæozoic glaciers has long been familiar to me, and this account of more ancient glaciers of Cambrian age is peculiarly acceptable.

The next sign of ice in Britain is found in the lower Silurian rocks of Wigtonshire and Ayrshire. In the year 1865 Mr. John Carrick Moore took me to see the Lower Silurian graptolitic rocks at Corswall Point in Wigtonshire, in which great blocks of gneiss, granite, &c., are imbedded, and in the same year many similar erratic blocks were pointed out to me by Mr. James Geikie in the Silurian strata of Carrick in Ayrshire. One of the blocks at Corswall, as measured by myself, is nine feet in length, and the rest are of all sizes, from an inch or two up to several feet in diameter. There is no gneiss or granite in this region nearer than those of Kirkcudbrightshire and Arran, *and these are of later geological date than the strata amid which the erratic blocks are imbedded.* It is therefore not improbable that they may have been derived from some high land formed of Laurentian rocks of which the outer Hebrides and parts of the mainland of Scotland form surviving portions. If so, then I can conceive of no agent capable of transporting large boulders and dropping them into the Lower Silurian mud of the seas of the time save that of icebergs or other floating ice, and the same view with regard to the neighbouring boulder-beds of Ayrshire is held by Mr. James Geikie. If, however, any one will point out any other natural cause still in action by which such results are at present brought about, I should be very glad to hear of it.

I must now turn to India for further evidence of the action of palæozoic ice. In the Himalayas of Pangi, S.E. of Kashmir, according to Medlicott and Blanford, 'old slates, supposed to be Silurian, contain boulders in great numbers,' which they believe to be of glacial origin. Another case is mentioned as occurring in 'transition beds of unknown relations,' but in another passage they are stated to be 'very ancient, but no idea can be formed of their geological position.' The *underlying rocks are marked by distinct glacial striations.*

The next case of glacial boulder-beds with which I am acquainted is found in Old Red Sandstone in Scotland, and in some places in the north of England, where they contain what seem to be indistinctly ice-scratched stones. I first observed these rocks on the Lammermuir Hills, south of Dunbar, lying unconformably on Lower Silurian strata, and soon inferred them to be of glacial origin, a circumstance that was subsequently confirmed by my colleagues, Prof. and Mr. James Geikie, and is now familiar to other officers of the Geological Survey of Scotland.

I know of no boulder formations in the Carboniferous series, but they are well known as occurring on a large scale in the Permian brecciated conglomerates, where they consist 'of pebbles and large blocks of stone,

generally angular, imbedded in a marly paste. . . . the fragments have mostly travelled from a distance, apparently from the borders of Wales, and some of them are three feet in diameter.' Some of the stones are as well scratched as those found in modern moraines or in the ordinary boulder-clay of what is commonly called the Glacial Epoch. In 1855 the old idea was still not unprevalent that during the Permian Epoch, and for long after, the globe had not yet cooled sufficiently to allow of the climates of the external world being universally affected by the constant radiation of heat from its interior. For a long time, however, this idea has almost entirely vanished, and now, in Britain at all events, it is little if at all attended to, and other glacial episodes in the history of the world have continued to be brought forward and are no longer looked upon as mere ill-judged conjectures.

The same kind of brecciated boulder-beds that are found in our Permian strata occur in the Rotheliegende of Germany, which I have visited in several places, and I believe them to have had a like glacial origin.

Mr. G. W. Stow, of the Orange Free State, has of late years given most elaborate accounts of similar Permian boulder-beds in South Africa. There, great masses of moraine matter not only contain ice-scratched stones, but on the banks of rivers where the Permian rock has been removed by aqueous denudation, the underlying rocks, well rounded and mammillated, *are covered by deeply incised glacier grooves* pointing in a direction which at length leads the observer to the pre-Permian mountains from whence the stones were derived that formed these ancient moraines.[1]

Messrs. Blanford and Medlicott have also given in 'The Geology of India' an account of boulder-beds in what they believe to be Permian strata, and which they compare with those described by me in England many years before. There the Godwana group of the Talchir strata contains numerous boulders, many of them six feet in diameter, and 'in one instance *some of the blocks were found to be polished and striated, and the underlying Vindhyan rocks were similarly marked.* The authors also correlate these glacial phenomena with those found in similar deposits in South Africa, discovered and described by Mr. Stow.

In the Olive group of the Salt range, described by the same authors, there is a curious resemblance between a certain conglomerate 'and that of the Talchir group of the Godwana system.' This 'Olive conglomerate' belongs to the Cretaceous series, and contains ice-transported erratic boulders derived from unknown rocks, one of which of red granite 'is polished and striated on three faces in so characteristic a manner that very little doubt can exist of its having been transported by ice.' One block of red granite at the Mayo Salt Mines of Khewra 'is 7 feet high and 19 feet in circumference.' In the 'Transition beds' of the same

[1] Mr. Stow's last memoir on this subject is still in manuscript. It is so exceedingly long, and the sections that accompany it are of such unusual size, that the Geological Society could not afford their publication. It was thought that the Government of the Orange Free State might undertake this duty, but the late troubles in South Africa have probably hindered this work—it is to be hoped only for a time.

authors, which are supposed to be of Upper Cretaceous age, there also are boulder beds with erratic blocks of great size.

I know of no evidence of glacial phenomena in Eocenė strata excepting the occurrence of huge masses of included gneiss in the strata known as Flysch in Switzerland. On this question, however, Swiss geologists are by no means agreed, and I attach little or no importance to it as affording evidence of glacier ice.

Neither do I know of any Miocene glacier-deposits excepting those in the north of Italy near Turin, described by the late eminent geologist, Gastaldi, and which I saw under his guidance. These contain many large erratic boulders derived from the distant Alps, which, in my opinion, were then at least as lofty or even higher than they are now, especially if we consider the immense amount of denudation which they underwent during Miocene, later Tertiary, and post-tertiary times.

At a still later date there took place in the north of Europe and America what is usually misnamed '*The* Glacial Epoch,' when a vast glacial mass covered all Scandinavia, and distributed its boulders across the north of Germany, as far south as the country around Leipzig, when Ireland also was shrouded in glacier ice, and when a great glacier covered the larger part of Britain, and stretched southward, perhaps nearly as far as the Thames on the one side, and certainly covered the whole of Anglesey, and probably the whole, or nearly the whole, of South Wales. This was after the advent of man.

Lastly, there is still a minor Glacial Epoch in progress on the large and almost unknown Antarctic continent, from the high land of which in latitudes which partly lie as far north as 60° and 62°, a vast sheet of glacier-ice of great thickness extends far out to sea and sends fleets of icebergs to the north, there to melt in warmer latitudes. If in accordance with the theory of Mr. Croll, founded on astronomical data, a similar climate were transferred to the northern hemisphere, the whole of Scandinavia and the Baltic would apparently be covered with glacier-ice, and the same would probably be the case with the Faroe Islands and great part of Siberia, while even the mountain tracts of Britain might again maintain their minor systems of glaciers.

Conclusions.

In opening this address, I began with the subject of the oldest metamorphic rocks that I have seen—the Laurentian strata. It is evident to every person who thinks on the subject that their deposition took place *far from the beginning of recognised geological time.* For there must have been older rocks by the degradation of which they were formed. And if, as some American geologists affirm, there are on that continent metamorphic rocks of more ancient dates than the Laurentian strata, there must have been rocks more ancient still to afford materials for the deposition of these pre-Laurentian strata.

Starting with the Laurentian rocks, I have shown that the phenomena of *metamorphism* of strata have been continued from that date all through the later formations, or groups of formations, down to and including part of the Eocene strata in some parts of the world.

In like manner I have shown that ordinary volcanic rocks have been ejected in Silurian, Devonian, Carboniferous, Jurassic, Cretaceo-oolitic, Cretaceous, Eocene, Miocene, and Pliocene times, and from all that I have seen or read of these ancient volcanoes, I have no reason to believe that volcanic forces played a more important part in any period of geological time than they do in this our modern epoch.

So, also, mountain chains existed before the deposition of the Silurian rocks, others of later date before the Old Red Sandstone strata were formed, and the chain of the Ural before the deposition of the Permian beds. The last great upheaval of the Alleghany Mountains took place between the close of the formation of the Carboniferous strata of that region and the deposition of the New Red Sandstone.

According to Darwin, after various oscillations of level, the Cordillera underwent its chief upheaval after the Cretaceous epoch, and all geologists know that the Alps, the Pyrenees, the Carpathians, the Himalayas, and other mountain-chains (which I have named) underwent what seems to have been their chief great upheaval after the deposition of the Eocene strata, while some of them were again lifted up several thousands of feet after the close of the Miocene epoch.

The deposition of salts from aqueous solutions in inland lakes and lagoons appears to have taken place through all time—through Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, Cretaceous, Eocene, Miocene, and Pliocene epochs—and it is going on now.

In like manner fresh-water and estuarine conditions are found now in one region, now in another, throughout all the formations or groups of formations possibly from Silurian times onward; and glacial phenomena, so far from being confined to what was and is generally still termed *the* Glacial Epoch, are now boldly declared, by independent witnesses of known high reputation, to begin with the Cambrian epoch, and to have occurred somewhere, at intervals, in various formations, from almost the earliest Palæozoic times down to our last post-Pliocene 'Glacial Epoch.'

If the nebular hypothesis of astronomers be true (and I know of no reason why it should be doubted), the earth was at one time in a purely gaseous state, and afterwards in a fluid condition, attended by intense heat. By-and-by consolidation, due to partial cooling, took place on the surface, and as radiation of heat went on, the outer shell thickened. Radiation still going on, the interior fluid matter decreased in bulk, and, by force of gravitation, the outer shell being drawn towards the interior, gave way, and, in parts, got crinkled up, and this, according to cosmogonists, was the origin of the earliest mountain-chains. I make no objection to the hypothesis, which, to say the least, seems to be the best that can be offered and looks highly probable. But, assuming that

it is true, these hypothetical events took place so long before authentic geological history began, as written in the rocks, that the earliest of the physical events to which I have drawn your attention in this address was, to all human apprehension of time, so enormously removed from these early assumed cosmical phenomena, *that they appear to me to have been of comparatively quite modern occurrence, and to indicate that from the Laurentian epoch down to the present day, all the physical events in the history of the earth have varied neither in kind nor in intensity from those of which we now have experience.* Perhaps many of our British geologists hold similar opinions, but, if it be so, it may not be altogether useless to have considered the various subjects separately on which I depend to prove the point I had in view.

REPORTS

ON THE

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Report of the Committee, consisting of Professor Sir WILLIAM THOMSON, Professor TAIT, Professor GRANT, Dr. SIEMENS, Professor PURSER, Professor G. FORBES, Mr. HORACE DARWIN, *and* Mr. G. H. DARWIN (*Secretary*), *appointed for the Measurement of the Lunar Disturbance of Gravity.*

THE Committee beg leave to report as follows:—

The sum of £30 granted in 1879 for the purposes of the Committee has been paid to Mr. G. H. Darwin.

Before the meeting of 1879 Mr. G. H. Darwin and Mr. Horace Darwin were making preparations for carrying out experiments with a view of detecting small variations in the directions of the force of gravity. With the aid of the above grant some preliminary experiments have been made during the past year by Mr. G. H. and Mr. H. Darwin in the Cavendish Laboratory of the University of Cambridge by means of an instrument of which the principle was suggested to the experimenters by Sir William Thomson.

The experiments have not as yet been carried sufficiently far to make it desirable to present a detailed report to the British Association. It may nevertheless be mentioned that results of some interest have been attained with regard to the warping of stone columns under the influence of minute changes of temperature or of small stresses.

The chief conclusion, however, to which the experimenters have been led is that it is now necessary to entirely re-design the apparatus. It seems probable that the experiments will occupy a considerable time, and may possibly prove expensive.

Under these circumstances the Committee think it expedient to defer the presentation of their Report and of the accounts until the meeting of the Association in 1881.

Supplementary Report.

The Secretary of this Committee having got in and paid an outstanding account since the Report was sent in, finds that nearly the whole sum granted for the purposes of the Committee in 1879 has been expended.

As, however, the experiments are still only in an incipient stage, it is necessary to defer the report of the results attained.

Under these circumstances the Secretary suggests the advisability of the continuation of the Committee on the Lunar Disturbance of Gravity for another year.

As the plan which the experimenters intend to pursue will involve some masonry work and the use of a good deal of copper for apparatus—an expensive material and difficult to work—it seems likely that future operations may prove expensive. The Secretary, therefore, ventures to suggest that the Association should grant a further sum of 30*l.* for the purposes of this Committee.

Thirteenth Report of the Committee, consisting of Professor EVERETT, Professor Sir WILLIAM THOMSON, Mr. G. J. SYMONS, Professor RAMSAY, Professor GEIKIE, Mr. J. GLAISHER, Mr. PENGELLY, Professor EDWARD HULL, Dr. CLEMENT LE NEVE FOSTER, Professor A. S. HERSCHEL, Professor G. A. LEBOUR, Mr. A. B. WYNNE, Mr. GALLOWAY, Mr. JOSEPH DICKINSON, Mr. G. F. DEACON, *and* Mr. E. WETHERED, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Professor EVERETT (*Secretary*).

OBSERVATIONS have been taken in the Talargoch Lead Mine, Flintshire (between Rhyl and Prestatyn), under the direction of Mr. A. Strahan, of the Geological Survey, and Mr. Walker, Chairman of the Board of Directors of the mine.

The top of the shaft is 190 feet above the level of the sea, and is at the foot of a hill 500 feet above the sea. The lowest workings are 900 feet below sea-level. The veins run across an angle of Carboniferous Limestone, bounded on both sides by faults which throw down coal-measure shale; and as the faults have a considerable inclination, the lowest workings run beneath the shale for a considerable distance. The limestone dips at angles varying from 45° to 55°, and is of two kinds, one white and massive, the other thin bedded black with thin shale partings.

There are levels at intervals of about 20 yards vertically, in the vein, most of which have been driven for some years; but all the observations have been taken in newly opened ground.

They have been taken by boring a hole 24 inches deep at a distance of from $1\frac{1}{2}$ to 5 yards from the fore breast, and either on the same day or the next day inserting one of the Committee's slow-action thermometers, with a foot of plugging consisting of dry rag and clay behind it. After an interval generally of four days the thermometer was taken out and read, then reinserted, and read again about a week later, the difference between the two readings never amounting to so much as half a degree.

The observations were taken at six different places in the mine, which are designated by the observers Stations I. to VI.; but in one instance, that of Station II., owing to the swelling of newly exposed shale, the hole

became distorted, so that after extracting the dry rag and clay, an hour was expended in working out the thermometer, the reading of which has therefore been rejected. The following is a list of the five remaining stations, arranged in order of depth:—

No. of Station	Depth from Surface in feet	Temperature Fahr.	Distance and Direction from Mostyn Shaft
IV.	465	53·4°	190 yds. S.W.
V.	555	52·9°	170 yds. S.E.
VI.	636	58·8°	840 yds. S.W.
III.	660	54·0°	120 yds. S.
I.	1041	60·8°	190 yds. N.E.

It will be observed that the order of the temperatures is not the same as the order of the depths; it therefore becomes important to describe the positions with some particularity.

Stations IV., V., and III. are near together in ground plan, IV. and V. being about 250 yards apart, and III. nearly midway between them, and they have all the same rock overhead between them and the surface, namely, black and white limestone.

At Station I. the rock overhead consists almost entirely of sandstones and shales, with thin coal-seams. At Station VI. it consists of white limestone and shale.

It may be mentioned that the temperature at VI. was observed on three several occasions, namely, January 14, January 21, and February 19, and was in each case found to be the same. Mr. Strahan further states that this station is near a large fault, which contains iron pyrites and gives off water charged with sulphuretted hydrogen; the temperature of the water as pumped up Walker's shaft from a depth of 770 feet, being 63° at the top of the lift. It seems probable that the decomposition of this pyrites may be the cause of the exceptionally high temperature at this station.

The comparison of the temperatures will be most clearly brought out by tabulating the rate of increase from the surface down to each station, as calculated from an assumed surface temperature, which may be fairly taken as 48°. As all the depths are considerable, an error of a degree in the surface temperature will not have much influence on the comparison, which stands thus:—

Station	Depth in feet	Excess above Surface	Feet per Degree
IV.	465	5·4°	86
V.	555	4·9°	113
VI.	636	10·8°	59
III.	660	6·0°	110
I.	1041	12·8°	81

Stations V. and III., which give the slowest rate of increase, are both of them in a vein called the 'South Joint;' and Stations IV. and I., which agree well with each other, though differing from the rest, are both of them in another vein called the 'Talargoch vein;' while Station VI. is in the rock. The horizontal distance between IV. and III. is only 120 yards: but if we attempt to deduce the rate of increase from comparing these two, we have an increase of only 0·6° in 195 feet. It thus appears that, notwithstanding the proximity of the two veins, their conditions as to temperature are very different.

Widely as the results differ among themselves, they agree upon the whole in showing that the average rate of increase is slow; and this

general result is in harmony with what has been found at the nearest localities mentioned in our previous reports, namely, Dukinfield and Liverpool. Here, as at Dukinfield, all the strata are highly inclined.

Some additional observations at Dukinfield have recently been made for the Committee, by Mr. Edward Garside, student of engineering in Queen's College, Belfast. The Astley Pit, in which they were taken, has now been carried to a much greater depth than it had extended at the time of Sir Wm. Fairbairn's observations, to which allusion was made in our Report for 1870. The two deepest seams of coal in it are called the 'Cannel Mine' and the 'Black Mine,' the former being the deeper of the two; they both slope downwards at about 15°, the deepest point being the far end of the Cannel Mine. The following is Mr. Garside's summary of the observations; the 'surface-depth' being distinguished from the 'shaft-depth' because the surface is not level, but slopes slightly in the same general direction as the seams. The shaft-depth gives the difference of levels, but the surface-depth, which is practically the same as the distance of the nearest point of the surface, is what we must use in computing the rate of increase of temperature.

Date in 1880	Seam of Coal	Surface Depth. Feet	Shaft Depth. Feet	Temperature of Strata. Fahr.	Temperature in Air Road. Fahr.	Distance from main Air Column. Yards
June 17	Cannel	2,700	2,754	$86\frac{1}{2}$	$75\frac{1}{2}$	160
„ 19	Black	$2,407\frac{1}{2}$	2,631	80	$78\frac{3}{4}$	630
„ 21	Cannel	$2,416\frac{1}{2}$	$2,482\frac{1}{2}$	81	79	600
July 2	Black	$1,987\frac{1}{2}$	$2,047\frac{1}{2}$	74	$71\frac{1}{2}$	460

The pit is described as being entirely free from water.

All the observations were taken with one of the Committee's slow-acting thermometers, in holes drilled in the floors at the far ends of newly opened horse-road levels; the holes being 4 feet deep and 2 inches in diameter. All the holes were free from cracks, and were in the same kind of rock—an argillaceous earth called 'warren earth.' They were allowed to stand for a short time, to allow the heat caused by drilling to escape. The thermometer was then inserted, and the portion of the hole between it and the mouth plugged with cotton waste and the dust which came out of the hole in drilling. After being left for forty-eight hours, it was taken out and read.

Arranging the observations in the order of the surface-depths, we have the following data:—

Seam	Surface Depth	Temperature	Feet per Degree from Surface
Black	$1,987\frac{1}{2}$	74	79·5
„	$2,407\frac{1}{2}$	80	77·7
Cannel	$2,416\frac{1}{2}$	81	75·5
„	2,700	$86\frac{1}{2}$	72

The numbers in the last column are calculated from an assumed surface-temperature of 49°, and show that the increase of temperature becomes more rapid as the depth increases. If, without making any assumption as to surface-temperature, we compare the observations among themselves, the two shallower give an increase of 6° in 420 feet, which is at the rate of 1° in 70 feet, and the two deeper give an increase of $5\frac{1}{2}$° in $283\frac{1}{2}$ feet, which is at the rate of 1° in $51\frac{1}{2}$ feet, a result which confirms the increase of rapidity with depth.

The greatest depth in Sir Wm. Fairbairn's observations was 685 yards

or 2055 feet, and the temperature which he found at this depth ($75\frac{1}{2}°$) is within less than a degree of the temperature which would be calculated from the observations now reported.

The Committee have to express their regret at the loss of two of their colleagues—Prof. Clerk Maxwell, and Prof. Ansted—by death, during the past year.

Report of the Committee, consisting of Dr. O. J. LODGE (*Secretary*), Professor W. E. AYRTON, *and* Professor J. PERRY, *appointed for the purpose of devising and constructing an improved form of High Insulation Key for Electrometer Work.*

IN the construction of the key it was considered desirable to secure as far as possible the following conditions :—

1. That the insulation should be nearly perfect.
2. That the conductors should have a very small electrostatic capacity.
3. That they should be entirely protected from all external induction by a metal case.
4. That the hand of the operator should work the moving parts from the outside of the case, so as neither to act inductively on the conductors, nor to electrify insulators by friction.
5. That there should be no friction whatever between insulators and conductors in the moving parts.
6. That all the insulating parts should be easily removable occasionally for cleaning purposes.
7. That the commercial price of the key should not be unreasonably high.

In the original form of the key the conductors were platinum wires suspended inside a metal case by silk threads, the leading wires being brought to them through large holes in the case. It was found, however, that this arrangement was rather too delicate and troublesome for general use, and it was impossible to artificially dry the air in the case because of the large holes in it.

It was determined, therefore, to abandon silk strings and to use rigid supports for the conductors, and to allow the conductors to protrude through small holes in the case, so that the leading wires might not have to enter the case to reach them.

For the supports it was ultimately decided to use, not ebonite, but glass, as the latter is more easily cleaned, and in a dry atmosphere has probably the better insulating power; moreover it is not liable to contract a coat of acid, which acting on the metal conductors gives rise to a feeble E.M.F. causing some keys to act as extremely weak batteries.

The insulators are four thin pillars of carefully selected glass, mounted in the case in such a way that they can be easily taken out and cleaned occasionally. Brass caps are cemented to the top of each of the pillars, which are so arranged that each cap is near a small hole in the side of the case, and a short thin rod ending in a binding screw is passed through this hole and screwed into each brass cap after they are in position.

Small ebonite plugs slide on these rods and ordinarily close the holes through which the rods pass, except when pulled out. When very good

insulation is required they are pulled out so as to leave the conductors free of the holes, touching nothing.

To each of one pair of brass caps a short brass pin is attached, the two projecting horizontally one above the other. To the other pair two brass or bronze flat springs are screwed, which project between the two pins attached to the other pair of caps. Except when depressed the springs both press upon the upper of the two pins and make contact with it. All the contact surfaces are gilt. Either spring can be depressed separately without bringing the hand near it, by means of a thin glass rod, which works through a hole in the top of the case, and which is shod with metal above and below, so that it may not be subject to any friction which might electrify it.

The piece of metal at the top is a brass cap sliding over a tube fixed in the top of the case in such a way as to exclude dust; it can be pressed down with the fingers, and is sent up again by a spiral spring. A pin and double bayonet-slot is also arranged so as to fix the piece permanently in either of three positions, viz., completely up and in contact with the top pin, completely down and in contact with the bottom pin, half-way or insulated.

In its present form the key is in principle simply an ordinary double reversing key turned upside down and shut up in a box.

The glass pillars are fixed to the lid instead of to the floor of the case for several reasons, one of which is that it economises space and reduces the height of the key. The lid can be unscrewed and taken out of the case with all the working parts *in situ*, which is very convenient. The floor of the case is quite free and can be removed at pleasure. A dish stands on it to contain pumice soaked with sulphuric acid whenever extra insulation is required. Without any artificial drying, however, the insulation is very good. The dish is made either of lead, or of glass protected from the working parts by a covering of wire gauze.

The key has been made by Elliott Bros. in two forms—one square, the other round. The round form of case is distinctly the cheaper; it necessitates a slight modification in the arrangement of the working parts, but it appears to be nearly as convenient as the other.

Report of the Committee, consisting of Professor CAYLEY, *F.R.S.*, Professor G. G. STOKES, *F.R.S.*, Professor H. J. S. SMITH, *F.R.S.*, Professor Sir WILLIAM THOMSON, *F.R.S.*, Mr. JAMES GLAISHER, *F.R.S.*, *and* Mr. J. W. L. GLAISHER, *F.R.S.* (*Secretary*), *on Mathematical Tables. Drawn up by* Mr. J. W. L. GLAISHER.

THE present Report relates to the factor tables for the fourth, fifth, and sixth millions, and to some results of the enumeration of the primes in the fifth million and the first five millions. In Section I. an account is given of the state of the work, two volumes of which have been published, while a portion of the third and concluding volume is already in type. Section II. contains in a condensed form results relating to the distribution of primes in the fifth million, obtained by enumerating the primes in

each hundred, or century, in that million: it is similar to Part I. of last year's Report, which related to the fourth million.

As the factor tables for the first five millions are now published, so that it is for the first time possible to extend the enumerations continuously from 0 to 5,000,000, it was thought desirable to give here in a tabular form the main facts relating to the distribution of primes over this range: these tables form Section III. The results are given very briefly, because it is hoped that by next year the series of tables will be complete as far as 9,000,000, and a more detailed examination is deferred till it can be rendered as complete as possible.

One of the objects to which enumerations of primes are most directly applicable is the examination of the degree of accuracy with which the numbers of primes in any given intervals are represented by certain formulæ which have been proposed for the purpose. A formula of this kind was proposed by Legendre, and another was independently obtained by Gauss, Tchebycheff, and Hargreave. Certain comparisons between the numbers of primes counted and the numbers given by these two formulæ for intervals between 0 and 5,000,000 are contained in Section IV.

I. *State of the Factor Tables for the Fourth, Fifth, and Sixth Millions.*

During the year the calculation for the three millions has been completed, and the printing of the tables has been steadily continued under the direction of Mr. James Glaisher. The volumes containing the factor tables for the fourth and fifth millions have been published, and twenty pages of the volume containing the sixth million are now printed and stereotyped.

The *fourth million* was published in December, 1879, by Messrs. Taylor and Francis. The table itself occupies 112 pages, and is uniform with those of Burckhardt and Dase. There is an introduction of fifty-two pages, consisting of eight sections and an appendix. The titles of the sections are (1) Manner of using the Table; (2) The Tables of Burckhardt, Dase, and Chernac; (3) Mode of Construction of the Table; (4) On Factor Tables; (5) On the Distribution of Prime Numbers; (6) List of Writings on the Distribution of Prime Numbers; (7) Results of the Enumeration of the Prime Numbers in the Fourth Million; (8) Application of the Table to the Calculation of Logarithms. The appendix contains a list of prime numbers from 1 to 30,341 with differences: this list was used in the determination of least factors by the multiple method. There is also a specimen of one of the lithographed sheets used in the calculation of the table, and from which the sieves were formed by stamping out certain of the squares. An abstract of the third section, which relates to the mode of construction of the table, appeared in the Report for 1878, and an abstract of the seventh section, which contains the tables derived from the enumeration of the primes in the fourth million, formed Part I. of last year's Report.

The introduction to this million is intended to apply to the whole three millions.

The *fifth million* was published in July of this year. The introduction, which contains eleven pages, consists of only two sections, the first of which relates to the manner of using the table, and the second to the results of the enumeration of the primes in the fifth million. An abstract of the latter forms Section II. of this Report.

The *sixth million* is still in the press, and the printing and stereotyping of the table will be completed early next year. It is intended to prefix to this volume an introduction containing the results of the enumerations for the whole nine millions over which the printed tables will then extend, with comparisons of the numbers found by counting with those given by Legendre's formula and the li x formula. A table of the values of li x from $x = 0$ to $x = 9{,}000{,}000$ at intervals of 50,000 is now in course of calculation, as also is a table of the values given by Legendre's formula for the same arguments. The results of these comparisons for intervals of 250,000 up to 5,000,000 are given in Section IV.

II. *Results of the Enumeration of the Primes in the Fifth Million.*

The following table, which is similar to that given on p. 47 of last year's Report, contains the chief results of the enumeration of the primes in the fifth million, arranged according to the numbers of primes in the centuries.

4,000,000 to 5,000,000.

n	Number of centuries each of which contains n primes										
	4,000,000 to 4,100,000	4,100,000 to 4,200,000	4,200,000 to 4,300,000	4,300,000 to 4,400,000	4,400,000 to 4,500,000	4,500,000 to 4,600,000	4,600,000 to 4,700,000	4,700,000 to 4,800,000	4,800,000 to 4,900,000	4,900,000 to 5,000,000	4,000,000 to 5,000,000
0	0	0	0	0	0	0	2	0	0	0	2
1	3	3	3	0	3	2	3	3	2	4	26
2	15	17	17	16	13	18	14	20	10	21	161
3	29	39	31	35	37	55	48	49	41	39	403
4	92	90	110	100	75	96	83	105	109	83	943
5	142	156	151	143	153	132	162	140	149	160	1488
6	201	195	206	212	207	193	193	188	199	200	1994
7	215	200	161	205	190	192	187	191	194	194	1929
8	133	137	166	133	163	155	141	138	130	137	1433
9	93	89	93	94	96	97	97	97	80	86	922
10	45	48	37	44	37	35	42	47	45	46	426
11	21	16	17	15	18	19	20	12	29	22	189
12	7	7	5	2	5	6	6	9	9	7	63
13	3	3	2	1	2	0	2	1	3	1	18
14	1	0	1	0	1	0	0	0	0	0	3
No. of primes	6628	6540	6510	6511	6613	6493	6523	6475	6554	6522	65,369

This table shows the number of centuries in each group of 100,000, each of which contains no prime, each of which contains one prime, two primes, &c. For example, between 4,000,000 and 100,000 there is no century containing no prime (*i.e.* consisting wholly of composite numbers), there are three centuries which contain each one prime, fifteen which contain two primes, and so on, there being only one which contains fourteen primes. The number at the foot of each column is the total number of primes in the group of numbers to which the column relates; thus, for example, there are 6,628 primes between 4,000,000 and 4,100,000.

The next table shows the numbers of primes in each successive group of 10,000 between 4,000,000 and 5,000,000. Thus, for example, between

4,000,000 and 4,010,000 there are 660 primes, between 4,010,000 and 4,020,000 there are 658 primes, and so on.

4,000,000 to 5,000,000.

	4,000,000 to 4,100,000	4,100,000 to 4,200,000	4,200,000 to 4,300,000	4,300,000 to 4,400,000	4,400,000 to 4,500,000	4,500,000 to 4,600,000	4,600,000 to 4,700,000	4,700,000 to 4,800,000	4,800,000 to 4,900,000	4,900,000 to 5,000,000
I.	660	663	670	662	641	653	662	652	658	651
II.	658	628	644	666	679	638	656	653	655	634
III.	668	652	663	641	683	646	645	643	631	653
IV.	677	632	628	656	656	631	651	663	678	655
V.	681	661	664	635	672	648	651	644	634	650
VI.	643	662	660	640	655	659	616	642	645	640
VII.	653	671	644	653	660	673	665	655	669	683
VIII.	670	651	656	661	646	650	666	628	636	661
IX.	653	673	632	662	683	640	667	657	669	654
X.	665	647	649	635	638	655	644	638	679	641
No. of primes	6628	6540	6510	6511	6613	6493	6523	6475	6554	6522

The following is a list of successions of composite numbers of ninety-nine and upwards occurring in the fifth million.

SEQUENCES OF 99 AND UPWARDS.

Lower Limit	Upper Limit	Sequence
4,044,077	4,044,179	101
4,047,157	4,047,257	99
4,131,109	4,131,223	113
4,166,893	4,166,999	105
4,234,537	4,234,651	113
4,297,093	4,297,199	105
4,315,607	4,315,709	101
4,359,403	4,359,503	99
4,447,321	4,447,423	101
4,478,423	4,478,527	103
4,535,717	4,535,819	101
4,536,179	4,536,283	103
4,571,107	4,571,207	99
4,596,731	4,596,833	101
4,640,599	4,640,717	117
4,652,353	4,652,507	153
4,665,553	4,665,653	99
4,686,709	4,686,811	101
4,738,651	4,738,777	125
4,783,873	4,783,973	99
4,958,021	4,958,131	109

This table shows that the 101 numbers between 4,044,077 and 4,044,179 are composite, and so on; the numbers in the first two columns being the primes which bound the sequences of composite numbers.

The introductions to the *Fourth Million* and *Fifth Million* contain similar tables giving the sequences of 79 and upwards.

III. *Results of the Enumeration of the Primes in the first Five Millions.*

The following table is similar in form to the first table of Section II.; each column relates to a million numbers, and the last column to the whole five millions. The last column but one, which refers to the fifth million, is of course identical with the last column in the table in Section II.

0 to 5,000,000.

n	Number of centuries each of which contains n primes					
	0 to 1,000,000	1,000,000 to 2,000,000	2,000,000 to 3,000,000	3,000,000 to 4,000,000	4,000,000 to 5,000,000	0 to 5,000,000
0	0	1	1	2	2	6
1	3	16	25	30	26	100
2	29	72	97	136	161	495
3	140	257	338	400	403	1538
4	372	667	775	862	943	3619
5	801	1253	1408	1480	1488	6430
6	1362	1743	1878	1929	1994	8906
7	1765	2032	1997	1849	1929	9572
8	1821	1612	1526	1561	1433	7953
9	1554	1182	1036	950	922	5644
10	1058	691	558	497	426	3230
11	592	311	227	221	189	1540
12	316	113	98	60	63	650
13	122	39	28	19	18	226
14	32	7	6	4	3	52
15	20	3	1	0	0	24
16	8	1	0	0	0	9
17	3	0	1	0	0	4
21	1	0	0	0	0	1
26	1	0	0	0	0	1
Number of primes	78,499	70,433	67,885	66,329	65,369	348,515

It will be seen from this table that the centuries with eight primes are the most numerous in the first million, the centuries with seven primes in the second and third millions, and the centuries with six primes in the fourth and fifth millions. It may be mentioned that the centuries with six primes are also the most numerous in the seventh, eighth, and ninth millions.

The 26-prime century is of course the first, namely, from 0 to 99, and the 21-prime century the second. In the first century 1 is counted as a prime.

The next table shows the number of primes in each group of 10,000 from 0 to 5,000,000, with differences. For example, the number of primes between 0 and 10,000 is 9,593, between 10,000 and 20,000 is 8,392; between 1,000,000 and 1,010,000 is 7,216; and so on.

0 to 5,000,000.

NUMBER OF PRIMES IN EACH GROUP OF 10,000.

	0 to 1,000,000		1,000,000 to 2,000,000		2,000,000 to 3,000,000		3,000,000 to 4,000,000		4,000,000 to 5,000,000	
	No. of primes	Difference	No. of primes	Difference	No. of primes	Difference	No. of primes	Difference	No. of primes	Difference
I.	9593		7216	8	6874	29	6676	32	6628	7
II.	8392	1201	7225	−9	6857	17	6717	59	6540	−12
III.	8013	279	7081	164	6849	8	6691	26	6510	30
IV.	7863	150	7103	−22	6791	58	6639	52	6511	−1
V.	7678	185	7028	75	6770	21	6611	28	6613	−102
VI.	7560	118	6973	55	6809	−39	6575	36	6493	120
VII.	7445	115	7015	−42	6765	44	6671	−96	6523	−30
VIII.	7408	37	6932	83	6716	49	6590	81	6475	48
IX.	7323	85	6957	−25	6746	−30	6624	−34	6554	−79
X.	7224	99	6903	54	6708	38	6535	89	6522	32
No. of primes	78,499		70,433		67,885		66,329		65,369	

The numbers of primes in each quarter million in the first five millions, with differences, are:

	Number of Primes	Difference
0 – 250,000	22,045	
250,000 – 500,000	19,494	2,551
500,000 – 750,000	18,700	794
750,000 – 1,000,000	18,260	440
1,000,000 – 1,250,000	17,971	289
1,250,000 – 1,500,000	17,682	289
1,500,000 – 1,750,000	17,455	227
1,750,000 – 2,000,000	17,325	130
2,000,000 – 2,250,000	17,150	175
2 250,000 – 2,500,000	16,991	159
2,500,000 – 2,750,000	16,922	69
2,750,000 – 3,000,000	16,822	100
3,000,000 – 3,250,000	16,761	61
3,250,000 – 3,500,000	16,573	188
3,500,000 – 3,750,000	16,566	7
3,750,000 – 4,000,000	16,429	137
4,000,000 – 4,250,000	16,437	− 8
4,250,000 – 4,500,000	16,365	72
4,500,000 – 4,750,000	16,271	94
4,750,000 – 5,000,000	16,296	− 25

and the numbers for the complete millions are:

	Number of Primes	Difference
First million	78,499	
Second „	70,433	8,066
Third „	67,885	2,548
Fourth „	66,329	1,556
Fifth „	65,369	960

The following table contains the two longest successions of composite numbers met with in each of the five millions:

Lower Limit	Upper Limit	Sequence
	First Million.	
370,261	370,373	111
492,113	492,227	113
	Second Million.	
1,357,201	1,357,333	131
1,561,919	1,562,051	131
	Third Million.	
2,010,733	2,010,881	147
2,898,239	2,898,359	119
	Fourth Million.	
3,826,019	3,826,157	137
3,933,599	3,933,731	131
	Fifth Million.	
4,652,353	4,652,507	153
4,738,651	4,738,777	125

In the 'Philosophical Magazine' for August, 1854, the late Mr. C. J. Hargreave determined the number of primes inferior to 5,000,000 at 348,527. His method, which is there described, consisted in calculating the number of numbers which are the products of two prime factors, of three prime factors, &c., and thus determining the total number of composite numbers between the limits in question. The number of primes in the five millions obtained by enumeration from the tables is 348,515. This includes unity as a prime, and it appears that Hargreave excluded unity, so that if it be included, his number would become 348,528, which differs by 13 from the number obtained from the tables.

IV. *Comparison of the numbers of Primes counted with the Values given by Legendre's and Gauss's Formulæ.*

Legendre's formula for the number of primes inferior to a given number x is

$$\frac{x}{\log x - 1{\cdot}08366}.$$

This expression Legendre published in the second edition of his 'Théorie des Nombres' (Part iv. 1808), and he there gave a table containing comparisons between the numbers obtained from it and the numbers obtained by counting up to 400,000. This table Legendre subsequently extended in 1816, after the publication of Chernac's 'Cribrum Arithmeticum,' to 1,000,000. It does not appear why Legendre assigned the value 1·08366 to the constant which occurs in his formula, but it is probable that this value was originally determined so as to render very close the agreement with the numbers counted in the earlier enumerations, and as the formula still continued to yield good results as far as the later enumerations extended, no attempt was made to improve the value at first assigned to it.

The logarithm-integral li x, where li x denotes the integral,

$$\int_0^x \frac{dx}{\log x}$$

was employed by Gauss early in the century to represent approximately the number of primes inferior to x; but his researches were not published till 1863.[1] This integral was also used for the same purpose by Tchebycheff [2] in 1848 and Hargreave [3] in 1849.

The following table exhibits the amount of deviation between the numbers of primes counted and the values given by Legendre's formula.

x	Number of primes counted	$\frac{x}{\log x - 1{\cdot}08366}$	Difference
250,000	22,045	22,035	− 10
500,000	41,539	41,533	− 6
750,000	60,239	60,269	+ 30
1,000,000	78,499	78,543	+ 44
1,250,000	96,470	96,488	+ 18
1,500,000	114,152	114,179	+ 27
1,750,000	131,607	131,663	+ 56
2,000,000	148,932	148,976	+ 44
2,250,000	166,082	166,140	+ 58
2,500,000	183,073	183,175	+102
2,750,000	199,995	200,095	+100
3,000,000	216,817	216,913	+ 96
3,250,000	233,578	233,636	+ 58
3,500,000	250,151	250,275	+124
3,750,000	266,717	266,835	+118
4,000,000	283,146	283,323	+177
4,250,000	299,583	299,744	+161
4,500,000	315,948	316,102	+154
4,750,000	332,219	332,400	+181
5,000,000	348,515	348,644	+129

The next table exhibits the deviations between the numbers of primes counted and the values of li x.

x	Number of primes counted	li x	Difference
250,000	22,045	22,094	+ 49
500,000	41,539	41,606	+ 67
750,000	60,239	60,350	+111
1,000,000	78,499	78,628	+129
1,250,000	96,470	96,573	+103
1,500,000	114,152	114,263	+111
1,750,000	131,607	131,746	+139
2,000,000	148,932	149,055	+123
2,250,000	166,082	166,215	+133
2,500,000	183,073	183,245	+172
2,750,000	199,995	200,160	+165
3,000,000	216,817	216,971	+154
3,250,000	233,578	233,688	+110
3,500,000	250,151	250,319	+168
3,750,000	266,717	266,872	+155
4,000,000	283,146	283,352	+206
4,250,000	299,583	299,765	+182
4,500,000	315,948	316,114	+166
4,750,000	332,219	332,404	+185
5,000,000	348,515	348,638	+123

[1] Gauss, *Werke*, t. ii.

[2] *Mém de l'Acad. de St. Pétersbourg* (*Sav. Etr.*) t. vi. or *Liouville*, t. xvii.

[3] *Phil. Mag.* July 1849. More detailed references to those papers will be found in Section V. of the Introduction to the *Fourth Million*, pp. 36, 37.

From these tables it appears that although the deviations are less for Legendre's formula than for the li x formula, the former increase in a more rapid ratio than the latter. As Legendre's formula contains a disposable constant, chosen so that the values given by the formula might represent well the results of the enumerations for comparatively small values of x, it is to be expected the deviations would for some time be less than in the case of the logarithm integral formula, in obtaining which x is is supposed to be very large.

The portion of the former of these two tables up to 4,000,000 has appeared in a paper 'On the value of the constant in Legendre's formula for the number of primes inferior to a given number,'[1] but the extension to 5,000,000 is new. This paper also contains comparisons between the numbers of primes counted and those given by the formulæ:

$$\frac{x}{\log x-1}$$

and

$$\frac{x}{\log x-1-\dfrac{1}{\log x}}$$

up to 4,000,000. These have also been extended to 5,000,000; but it seems scarcely worth while to give the tables here, as the extension amounts to only one million.

Report of the Committee, consisting of Professor SYLVESTER (*Chairman*), Professor CAYLEY, *and* Professor SALMON, *appointed for the purpose of calculating Tables of the Fundamental Invariants of Algebraic Forms.*

IN consequence of the academical engagements of Mr. (now Dr.) F. Franklin, the trained and skilled assistant in the computation of the tables, only a small portion (8*l.* 5*s.*) of the 50*l.* granted by the Association has been expended.

With this sum the tables for the generating functions and groundforms of all single quantics, up to the 10th order inclusive, have been corrected and completed, and the tables relating to binary systems of quantics for all combinations of orders up to the 4th inclusive, recalculated. The results have been published *in extenso* in the 'American Journal of Mathematics.'

This revision has led to the discovery that two of the forms included in the table of ground-forms for a pair of cubics previously accepted as correct are composite forms, and should be omitted from the catalogue.

The table affected with this error had been calculated by the German mathematicians after Gordan's, and by Mr. Sylvester after an entirely different method, and the results were in perfect but fallacious accord.

The German method, it may be stated, never offers a complete guarantee against the occurrence of an error of this nature; its per-

[1] *Proceedings of the Cambridge Philosophical Society*, vol. iii. pt. vii. pp. 295–308 December 8, 1879).

petuation in the table as calculated by Mr. Sylvester was due to an arithmetical oversight on his part.

The detection of this grave error is due to the fortunate circumstance of the co-operation of Dr. Franklin, whose skill, fidelity, and accuracy as a computer it is impossible to praise too highly.

His time being now again available for undertaking this kind of work, for which he possesses unrivalled aptitude, the Committee request a renewal of the grant of 50*l.* for carrying it on.

Report of Observations of Luminous Meteors during the year 1879–80, *by a Committee consisting of* JAMES GLAISHER, *F.R.S.*, *&c.*, E. J. LOWE, *F.R.S.*, *&c.*, Professor R. S. BALL, *F.R.S.*, *&c.*, Professor G. FORBES, *F.R.S.E.*, WALTER FLIGHT, *D.Sc.*, *F.G.S.*, *and* Professor A. S. HERSCHEL, *M.A.*, *F.R.A.S.*

TWENTY annual reports having been already presented by this Committee since its first appointment in the year 1859, it is proposed in this, its twenty-first report, to review the result of the records and researches upon which (independently of the twelve preceding annual reports presented by Professor Baden-Powell) the Committee has during that long period been engaged.

In a treatise on 'Atmospheric Phenomena,' published by Mr. E. J. Lowe (one of the present, as well as an original member of this Committee,) in the year 1846, a copious collection of accounts of halos, auroras, and other unusual meteorological appearances, omitting, however, notes of fireballs and shooting stars, served, for the first time probably to many English readers, an important purpose in separating entirely the latter class of phenomena from those equally conspicuous and notable appearances which are of a purely meteorological origin and signification. The example of orderly arrangement of such descriptions which this work supplied was followed up and soon afterwards supplemented by the records of ordinary and extraordinary observations of luminous meteors begun by Professor Baden-Powell in the year 1855, and continued in subsequent annual reports of the British Association until the present time.

Immensely as the theory of meteor-systems has progressed during the long season of attention which has thus been directly bestowed upon them, the apparitions of fireballs and falling stars are still as striking and remarkable phenomena as they used formerly to be, and in some important respects also they remain just as truly problematical 'exhalations of the skies' as they were in former days. For although they are now known to be astronomical bodies, instead of objects depending on the winds and other uncertain meteorological conditions for their various aspects and production, yet no astronomical theory has yet been discovered or constructed sufficiently far-reaching and adapted to account at the same time satisfactorily both for the well-known occurrences of meteor-showers, and also for sporadic meteors, including the rarer phenomena of fireballs and aërolites.

References and allusions are abundantly made in the later years of these Reports both to the well-known discovery of the clustering together

of meteoric showers and certain periodic comets in the same circum-solar orbits, and also to the general theory of gatherings of star-dust in nebular bodies, applied to explain the origin of all classes of meteoric phenomena by Schiaparelli.

In recent years' appendices to the Reports the additions to our knowledge of the mineralogical structure and probable past history of aërolites is also amply reviewed; and the real paths of aërolitic and detonating meteors have in several instances been found from observations. A recapitulation of these leading views, and of the observations chronicled in aërolitic and meteoric parts of the Reports during the latter and larger part of the long period of their continuation, leads to the conclusion that little (if any) similarity of character can yet be confidently recognised to exist between aërolites, or detonating fireballs and the equally rare and magnificent meteoric phenomena of cometary star-showers.

The intermediate class of sporadic fireballs and shooting stars has been largely and closely examined and discussed, with consequences of the greatest importance to their scientific discrimination and description. The number of meteor-showers or radiant-points proved to be productive of ordinary displays of shooting stars has been greatly multiplied by observations and reductions; some few of them, in particular, being shown to be limited and confined to one or two days only of duration, in the annual dates of their appearance.

Fireballs of various magnitudes, of whose real paths simultaneous observations furnished good determinations, have not unfrequently been shown to be conformable to well-established radiant-points of shooting stars; and among the many hundreds of meteor radiant-points that have now been recorded, there is also sufficient evidence to show that many of the ordinary meteor-systems which they denote may very probably be following in the trains or orbits of certain formerly recorded comets.

Although presumptive views of a naturally wide distinction between aërolites and cometary shower-meteors are far from being yet refuted and explained away by recent theories and observations; yet the real paths of more than one detonating meteor have now been retraced to recognised ordinary radiant-points of shooting stars. The course of the large detonating fireball of Nov. 23, 1878, moreover, while it was strictly conformable to the well-marked radiant-point of the α-Taurids of November, presented also a very close accordance with the somewhat uncertainly determined orbit (because founded on rather scanty observations) of the periodic comet of 1702.

Much aid, it will be seen from this short outline of the Committee's labours during twenty years, has been afforded by its annual compilations to advance the present astronomical theory of shooting stars with materials of observation and by reviews of contemporary speculations.

The opportunities of which the Committee has hitherto been able to avail itself for correspondence and reductions of the observations annually received have not been adequate during the last two years for producing a complete category of their yearly undertaking. A detention like that required last year of some of the meteor contributions, and a deferment for a season of some reviews of printed memoirs on meteoric subjects, must accordingly be granted for the present, until the occasion may occur when a more convenient opportunity may offer itself for their presentation.

In the following appendix of this interim Report some errors are corrected of which the occurrence in the last two years' Reports passed undetected until after the publication of the volumes in which they were accidentally recorded. The earliest opportunity within its reach is now taken by the Committee to rectify these errors and to point out some errors in earlier Reports, to the appearance of which the brief survey of those Reports required for preparing the above short outline of the whole series of them has been the immediate occasion of drawing the Committee's attention. In another appendix, by Dr. Walter Flight, the occurrences of stonefalls, and abstracts of the analyses and discussions relating to them, which have taken place during the past year, are recorded.

Appendix I.

Revisions and Corrections of real paths of Meteors, and of other results of observations contained in the Reports of the last two and of some preceding years.

During the first years following the appointment of the Committee in the year 1860 for the collection of meteor observations, the importance of noting the radiant-points of observed meteors' tracks was not yet recognised, and was far from being generally practised and regarded. The real directions of flight of many shooting-stars and fireballs, the positions of whose real courses were found from simultaneous observations during several years previous to 1866, were accordingly only indicated, if at all, by the altitude and azimuth of the point from which the meteor proceeded or was directed in its line of flight towards the earth. Many of the meteors of which the real paths were investigated from more or less plentiful accounts of their appearance, in the appendices of these reports for the years 1860–65, were brilliant and sometimes detonating fireballs, besides some smaller shooting-stars. Among the adjustments needed to accommodate the rough observations to each other the choice and deduction of the radiant-point had at that period of the Committee's first proceedings not yet acquired the significancy with which on astronomical grounds it has more recently been invested, the principal objects of those earlier determinations having simply been to obtain the real heights and the lengths of path and velocities of the meteors' flights. Fair weight for determining the radiant-point was accordingly not always allowed to the best recorded observations for this purpose; and some obvious radiant-points like those of the 'Leonids,' &c., not being then established; considerable errors from this cause, and occasionally also from mistaken calculations, have been detected in a review of the many real paths described in the above-named part of these reports as regards the directions, or as concerning the astronomical positions in right-ascension and declination of the radiant-points from which those fine meteors were directed. The radiant-point positions given in the subjoined list sometimes differ slightly, from fresh projections and comparisons of the best observations, from those of the real paths adopted in the earlier reports. In cases where the errors discovered are, from various causes, of much larger magnitude, however, than these small emendations of the original reductions, the nature of the hitherto unnoticed misconstructions is stated and explained in notes which are appended to the list.

RADIANT-POINT POSITIONS OF FIREBALLS AND SHOOTING-STARS DOUBLY OBSERVED DURING THE YEARS 1859–65.

Reference numbers to the subjoined notes	Date	Hour G.M.T. or (local time)	General size and place of appearance	Adopted radiant-point: α δ	Adopted radiant-point: By nearest fixed stars	Comparisons with known radiant points	Reference; years a page of earlier volumes of these reports.
		h m s					
1	1859, Oct. 25	(7 15 p.m.)	= ☽. Holyhead and Ireland	41° + 17° (or ? 54 + 18) ± 10°	(η Tauri)	Taurid I.	1861, pp. 2, 28, and 1863, p. 318
2	Nov. 15	9 30 a.m.	Detonating. Dennisville; New York, &c., U.S.A.	About 237 + 32	π, ρ Serpentis	—	1860, p. 12
2*a*	1860, Aug. 6	7 38 p.m.	U.S. America. Large meteor	About 305 − 45	(H. A. Newton.)	—	1863, p. 337
3	1860, Nov. 1	8 30 p.m.	= ♃ Beeston Observatory, &c	55 (± 10°) + 20°	Near η Tauri	Taurid I.	1861, p. 6, and 1863, p. 319
4	1861, July 16	10 15 p.m.	> ♀; North Sea	285 − 20 (± 8°)	π Sagittarii	☄ 1770 I. (Lexell's) ☋ to ☊, July 8 to Aug. 6, 280–21	1862, pp. 2, 77
5	July 16	11 32 p.m.	½ ☽; English Channel	21 + 35 (± 4°)	Near β Andromedæ	—	1862, pp. 4, 78
6	Aug. 6	11 21 p.m.	> ♀ London and Manchester	310 − 25 (± 5°)	Near ψ Capricorni	—	1862, pp. 4, 78. (See the note, subjoined)
7	Nov. 12	5 49 p.m.	= ☽; Bristol, &c.	63 + 27 (± 5°)	φ (near η) Tauri	Taurid I.	1862, pp. 22, 79
8	Nov. 19	9 38 p.m.	Detonating. Paris to Norfolk	About 55 + 5 (?, ± 10°)	Near ν Tauri	? Taurid I. (Projection of the best observations)	1862, pp. 23, 79
9	Dec. 3	—	Detonating. Dessau, Germany	Near the North Pole (Heis)	Near Polaris	—	1862, p. 80

10	Dec. 24	9 to 11 p.m.	Sevenoaks, Kent, bright star-shower 30 per hour	On the ecliptic, in Taurus (A.S.H.)	Near Aldebaran	—	1862, pp. 40, 80
11	Dec. 8	8 16 p.m.	Detonating. Lancaster	$91 + 18 (\pm 10°)$	(ζ Tauri 82 + 21)	Taurid II.	1862, pp. 32, 79
12	1862, Jan. 28	11 4 p.m.	Shooting star; Leicestershire? to Cheshire?	$203 + 5 (\pm 5°)$	Near ζ Virginis	(By direct projection of the apparent paths)	1862, pp. 46, 80. (See the subjoined note)
13	Feb. 2	8 20 p.m.	= ☽. Dorsetshire to Derbyshire	$55 + 17 (\pm 10°)$	Near η Tauri	—	1862, pp. 46, 80
14	Feb. 23	9 25 p.m.	= ½ ☽. Derbyshire? to North Wales	$220 + 30 (\pm 15°)$	Near ϵ Böotis	—	1862, pp. 54, 80
15	Sept. 19	10 15 p.m.	= ☽ Canterbury to Oxford	$30(\pm 3°,) + 4(\pm 8°)$	Near ξ_1 Ceti	—	1863, pp. 219, 319
16	Sept. 22	10 22 p.m.	= ♃ London and Sussex	$300 (\pm 6°) + 12 (\pm 3°)$	Near ρ Aquilæ	—	1863, pp. 220, 320
17	Sept. 25	6 15 p.m.	= ¼ ☽, in twilight. Petworth to Salisbury	$345 + 20 (\pm 4°)$	½ (α β) Pegasi	—	1862, p. 76, and 1863, p. 320
18	Sept. 25	6 30 p.m.	= ½ ☽. Wiltshire to Cornwall	$15 + 28 (\pm 15°)$	Near τ υ Piscium	—	1862, p. 76, and 1863, pp. 222, 320
19	Nov. 16	10 45 p.m.	2 × ♀. South of Cornwall	$110 + 8 (\pm 8°)$	Near β Canis Minoris	—	1863, pp. 230, 320
20	Nov. 26	6 40 p.m.	= ½ ☽. Detonating. Selkirk to Lockerby	$105 + 53 (\pm 8°)$	Near g Lyncis	—	Ibid.
21	Nov. 27	5 47 p.m.	= ½ ☽, Detonating. The Scheldt to Normandy	$102 + 26 (\pm 5°)$	Near ϵ Geminorum	Geminid (?)	Ibid.
22	1863, Jan. 27	5 30 p.m.	= ½ ☽ ?; in twilight. Sterling and Perthshire	$13 - 18 (\pm 15°)$	Near β Ceti	—	1863, pp. 242, 321
23	Feb. 7	6 30 p.m.	= ☽; in twilight. Hebrides to Mull of Cantire	$270 + 35 (\pm 10°)$	Near θ Herculis	—	1863, pp. 244, 321

RADIANT-POINT POSITIONS OF FIREBALLS AND SHOOTING-STARS DOUBLY OBSERVED DURING THE YEARS 1859–65—(*continued*).

Reference numbers to the subjoined notes	Date	Hour G.M.T. or (local time)	General size and place of appearance	Adopted radiant-point		Comparisons with known radiant points	Reference; years and page of earlier volumes of these reports
				α δ	By nearest fixed stars		
		h. m. s.					
24	March 23	8 30 p.m.	= $\frac{1}{6}$ ☽. English Channel	243 + 57 (± 4°)	Near θ Draconis	—	1863, pp. 252, 323
25	Aug. 8	10 58 p.m.	= ♀. English Channel	18 + 29 (± 2°)	Near τ Piscium (by projected paths)	—	1863, p. 270, and 1864, p. 90
26	Aug. 10	(9 30 p.m.)	= $\frac{1}{2}$ ☽. Venice and Lombardy.	27 + 52 (± 6° ?)	Near 4 Persei	Perseid II. (?) Streak 4 minutes	1863, pp. 274, 335, and 1864, p. 90
27	Aug. 12	12 3 a.m.	> ♀. Hampshire	49 + 58. [At 60 + 70 by projection.]	B C Camelopardi. [Near c Camelopardi]	Perseid I. [?] With streak; lit up the landscape	1863, pp. 314, 324
28	Sept. 5	9 55 p.m.	Shooting star. London and Wisbech	16 + 27 (± 2°)	Near τ Piscium. (By projected paths)	—	1864, pp. 4, 90
29	Dec. 6	10 7 45 p.m.	Shooting star. London and Hawkhurst	84 + 12 (± 2°)	$\frac{1}{2}$ (λ ν) Orionis; (by projection)	[? Taurid II.; ζ Tauri at 82 + 21]	1864, pp. 22, 91. (See the subjoined note)
30	Dec. 12	5 35 p.m.	2 × ♃. Oundle and Nottingham	105 + 27 (± 6°)	Near τ Geminorum	Geminid. Streak 7° or 8°	1864, pp. 22, 91
31	Dec. 27	6 55 p.m.	= $\frac{1}{2}$ ☽. English Channel to Dorsetshire	81 + 22 (± 15°)	Near ζ Tauri	Taurid II. (?)	1864, pp. 28, 92
32	1864, Jan. 7	8 36 p.m.	$\frac{2}{3}$ ☽. Somersetshire	near η Eridani (?), at 42 −9	[or from Orion, or Cancer ?]	By its slow halting motion, probably a γ Eridanid	1864, pp. 30, 92
33	July 4	10 0 p.m.	= $\frac{1}{2}$ ☽. Royal Observatory, Greenwich, and North Wales	190 + 50 (±15°)	Near ϵ Ursæ Majoris	—	1864, pp. 46, 92

34	Aug. 6	10 20 p.m.	Large fireball. North Sea.	270 + 35 [or ? 290 + 30] ± 15°	Lyra [or ? near β Cygni]	? Cygnid; slow speed, 3 seconds	1864, pp. 52, 92
35	Aug. 9	12 52 a.m.	= $\frac{1}{3}$ ☽. Hawkhurst and Paris.	320 − 15 (± 8°)	Near δ Capricorni. By projected paths	μ Aquariad	1864, pp. 56, 92. (See the subjoined note)
35*a*	1864, Aug. 9	11 3 p.m.	Royal Observatory, Greenwich, and Hawkhurst.	28 + 58 (± 2°)	Near χ Persei. (By the projected paths)	Perseïd I., or Perseïd II. (?)	1864, pp. 60, 62, and 93. (See the note on the last meteor)
36	Aug. 10	(8 45 or 8 50 p.m.)	Large meteor. Lake Maggiore, Italy.	238 − 27 (± 15°)	Near Antares	—	1864, pp. 70, 92
37	Aug. 26	11 0 p.m.	= $\frac{1}{2}$ ☽. Wales; and West of England.	338 + 10 [or ? 343 + 17] (± 5°)	Near α Pegasi	A fine, well-observed Pegasid	1864, pp. 88, 93
38	Aug. 31	10 30 p.m.	$\frac{1}{6}$ ☽ (?). South of England.	130 (± 15) + 50 (± 5)	Near ι κ Ursæ Majoris	—	1864, p. 90, and 1865, p. 120
39	Nov. 11	5 35 p.m.	= full ☽. South of France.	83 + 35 (± 10°)	Near θ Aurigæ	—	1864, pp. 78, 120; 1879, pp. 91, 108. (See the subjoined note)
40	Nov. 20	8 50 p.m.	> full ☽. Beeston Observatory, &c. Detonating.	193 + 81 (± 10°) By projected paths	Near Polaris	—	1865, pp. 80, 121
41	1865, Feb. 21	9 25 p.m.	= full ☽; detonating. Fife and Perthshire.	255 + 55 (± 20°)	Near μ Draconis	—	1865, pp. 90, 122
42	April 30	12 45 a.m.	> ♀; (? detonated). Lichfield to Oxford.	70 + 50 (± 8°)	Near Capella	—	1865, pp. 98, 122

Notes.—*Rectification of some Meteor-tracks referred to in the present list.*

No. 6.—The real path of this meteor given at p. 78 of the volume for 1862 of these Reports is entirely erroneous from an accidental perversion in the calculation of one of the simultaneous observations. The computed path rests upon a supposed foreshortened view of the meteor at Manchester near ϵ Pegasi; but the star named in Mr. Baxendell's observation of the meteor there was ϵ Capricorni. The real flight of the meteor was therefore much lower than was supposed; and so far as the correction which it requires affects the position of the radiant-point, the original observations have again been projected and compared together. The most probable place of the radiant-point obtained from the new comparison of the recorded tracks is that near ψ Capricorni which is assigned to the meteor in the present list. The August shooting-stars (A,B,C,D,E,) of which approximate real paths are given on the same page of the volume of Reports for 1862 (all of them apparently scattered Perseïds) were too roughly observed to allow any dependence for useful comparisons to be placed on their astronomical radiant-points. The positions of those points were only guessed or indicated loosely from the observations to assist the remainder of the calculations.

No. 12.—The direction and position of the real path of this meteor given at page 80, in the above volume of these Reports, are, by some mistake made in the graphical projections, greatly at variance with the precise and accordant observations from which they are derived. The meteor's horizontal flight was directed almost exactly from east to west instead of (as it is described) from about thirty degrees south of east. The correction, corresponding to this needful emendation of the real path, is introduced in the present list in the observed astronomical position of the meteor's radiant-point.

The radiant here adopted of the meteor No. 14, is also, to accord more perfectly with the best accounts, placed fifteen or twenty degrees nearer to the true east point than the position at the same altitude in due N.E., which it is assumed to have occupied in the description given at the same page of the above year's Report, of that fireball's real path.

In the account of the real path of the fireball of February 7, 1863 (at page 321 of the volume for that year), the Mull of Galway is accidentally misstated as the locality of its end-point, instead of the Mull of Cantire.

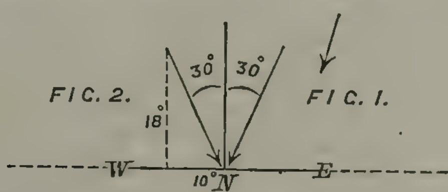
No. 29.—The two shooting stars described as simultaneously observed on the morning of November 14, 1863, at page 91 of the volume of these Reports for the year 1864, were unquestionably 'Leonids'; but no experience of the meteors of that shower having at that time been yet obtained, their real character was not suspected. The provisional radiant-points adopted to accommodate the somewhat discordant observations to each other for calculating their heights, are consequently quite erroneous; and some mistakes of deduction of the real paths seem also to have been committed in the process of the graphical projections. Although they emanated from the direction of Leo's Sickle, leaving the well-known luminous streaks upon their tracks, the simultaneous views recorded of their flights are not sufficiently distant from each other on a map to afford, by the backward prolongations and intersections of the tracks, astronomical positions of their respective radiant-points which would be accurate enough for insertion in the present list.

The teeming multitude of accounts preserved of the great fireball of December 5, 1863, again, as noticed in the paragraph just following those relating to the above two shooting-stars, are unavailable (although strenuous attempts to interpret them were made in contemporary reviews) to furnish anything of sufficient certainty regarding the real direction of that splendid fireball's flashing, perhaps abruptly deviating and deflected course, to form a record worth placing and including for preservation in the present list.

The provisional radiant-point adopted in the paragraph of the same Report-Appendix next following those just noticed, on the real path of the shooting-star (No. 29) of Dec. 6, 1863, is placed, without much departure from the observations, due east, and nearly horizontal. But the backward point of intersection of the two nearly adjacent tracks is yet about S.E., altitude 40°. As there appears no reason to assume a low radiant-altitude, and a nearly horizontal motion of this slow-moving short-pathed meteor through the air, from its observed appearance, it seems a more correct procedure to comply with the evidently exact and careful directions of the two recorded paths in fixing the radiant-point position at their actual point of intersection. This is accordingly the point given as a very well-determined radiant-point of the shooting-star in the present reconstructed list.

Nos. 35, 35*a*.—The real earthward course of the fine bolide of August 9th (a.m.), 1864, described (on page 92 of the volume for that year of these Reports) as concluded from the simultaneous views of the meteor obtained at the Luxembourg Observatory in Paris, and at Hawkhurst, in Kent, must, it appears, be rejected and renounced as quite wrongly laid down and represented. According to the note by M. Chapelas Coulvier-Gravier of its appearance in Paris, given without doubt correctly (at p. 56) in the general catalogue of that year's Report, the meteor passed at Paris from an altitude of eighteen degrees, ten degrees *west of north* to the north point of the horizon. But the recorded real path proceeds from the assumption that the meteor's course at Paris was from 10° east of north towards the true north point.

Small as the difference is (shown in the accompanying figures, 1 and 2), between the supposed and really recorded appearances of the meteor's path as seen in Paris, the effect upon the radiant-point, from the meteor's position in the northern sky, at both the stations of the double observation is prodigious. Instead of being between Perseus and Cassiopeia (E.N.E., altitude 60°), as it was represented, the meteor's real radiant-point was



considerably south of the equator, in Aquarius or Capricornus, where the two recorded apparent paths prolonged backwards, then intersect each other in the sky. The whole account of the fireball's appearance itself affords the strongest evidence of its being an 'Aquariad,' travelling, as this comparison shows it to have been, with moderate speed, and with a

slightly sloping path towards true north, at the not unusual height of fifty-five to forty-five miles above the sea, midway between Harwich and Ostend. It is, on the other hand, just as signally inconsistent with the usual character of the swift, streak-leaving August Perseïds and Cassiopeiads, as well as with the great height of expansion and disappearance over a point of the North Sea in the neighbourhood of Holland. Accordingly, although the meteor's course was mapped at both of the observers' stations so far from its southern radiant-point, yet from the precise character of the two descriptions, and their nearness to the point of *convergence* of the tracks, we may still regard the concluded radiant-point as very reliably established. It was on the ecliptic near the middle of the last sign but one before the vernal equinox, between Aquarius and Capricornus.

The direction of flight from altitude 24°, azimuth W. from S. 221°, noted in a description in the Report of the year 1864, accompanying the description just discussed, of the real path of another August meteor of the same date simultaneously observed at the Royal Observatory, Greenwich, and Hawkhurst, disagrees with the rest of the description of the path, to which a radiant-point at altitude 39°, azimuth 226° would correspond. The radiant-point directly given by projections of the recorded apparent tracks, is 28° + 58°, near χ Persei, corresponding to altitude 45°, azimuth 228°, showing that the altitude, at least, of the slope of path in the table of that shooting-star's reduction, has been accidentally misrepresented. The radiant near χ Persei given directly by the recorded tracks is that which has been adopted in the present list.

No. 39.—See the remarks on the corrections in the list, below, of the volume for 1879 of these Reports, pp. 108 and 120, for a new observation and reduction of this meteor's real track.

Rectifications of Errata, and of some false conclusions contained in the Reports on Meteor Observations for the years 1878 *and* 1879.—The following recapitulation of some *errata* and defects occurring in different portions of the last two years' Reports are arranged with reference to the lines and pages of the respective volumes of these Reports where they will be found, for greater ease and simplicity of their discovery and correction. Remarks on the corrections which they require are given in accompanying notes when the nature or magnitude of the emendations are such as to call for explanations and elucidation.

On account of the existence of several such material oversights, arising from the length of the Reports, and from lack of opportunities, which the Committee has had to regret during the last two years, for full and careful summaries of meteor records and descriptions, it is found necessary to condense the comments on these erasures as much as possible. Such rectifications of them, accordingly, as have already been published elsewhere are referred to occasionally in the notes, for further particulars of the expositions and reconsiderations which they have received. Sufficient revisions of the several imperfections are only intended to be here afforded to render the substance of the last two years' Reports as free from contemporaneous faults and misconstructions at the time when they were presented, as these Reports have generally been in former years.

Errata for correction in the Volume of these Reports for the year 1878.

Page	Line	Corrections and Remarks
260	12.	*For* Market Harborough *read* Coventry.
267	(3.)	(In the column 'Nearest known Radiant-point, &c.'), *for* D., 8 (1877) *read* Denning (Dec.–Jan., 1876–77).
267	(15 from foot.)	(In the column 'Length of Path, &c.'), *for* about 7 sec.; velocity $18\frac{1}{2}$ *read* 3 or 4 secs.; velocity about 35 (parabolic velocity 33).
285	(4.)	(In the column 'Observer, &c.'), *erase the small woodcut.*
296	(4.)	(In the column 'Position, &c.'), *for* passed through an hour angle, &c., *read* disappeared just below η Ursæ Majoris.
304	19.	*To* vol. for 1872 *subjoin the foot-note:* * In the note at p. 103 of that volume *for* 160 + 51 *read* 150 + 61; *and for* 155 + 47 *read* 160 + 49; (Heis M_8, 1864 and 1867; = 162 + 59, 1877.)
304	25.	*For* 155 + 47 *read* 160 + 49.
304	16 from foot.	*For* Beckingham *read* Rockingham.
310	7 from foot.	*For* vol. for 1878 *read* vol. for 1877.
333	2 from foot.	*For* near ϵ *read* near ϵ, or (more exactly) near δ.
335	4 to 27.	*Dele all the text from* and also . . . *as far as* Perseïds of August 10. *In the foot-note, for* meteor-tracks of this shower . . . . on August 10 and 11, *read* meteor-tracks of the shower . . . . on August 10 and 11, 1871. *And for* the fellow-comet, 1870 I . . . . *to end of the note, read* a near companion radiant-centre.
342	3 to 8.	*For* The cases . . . . are perhaps exceptions *read* The case of the accordance noticed above (p. 326) between the comet 1825 II. ☊ (− 0·115, Oct. 7, 134° + 77°) and a briefly enduring meteor-shower, noted by Mr. Denning on the nights of October 3 and 4, 1877, at 130° + 79°, may perhaps be an exception.
,,	4 from foot.	*After* (26 to) 27 *add* {N. 50, ℘ 1870 I ☊; *for* 43·5 + 53 *read* 25·5 + 45.}
		[*Note*—This last and the two preceding corrections relate to an error, rectified by the last, of the radiant-point assigned in the cometary radiant-list of the Report of the year 1875, to the comet 1870 I. By the corrected place this comet is entirely separated from all appearance of connection with the ordinary August Perseïd-shower; and the conjecture raised in the above noted passages of the possible origin of a double radiant-centre in the August Perseïd-shower of 1878 from the concurrent presence of two nearly coincident comet-orbits in connection with the meteor-stream, is entirely and at once dismissed by the note of the more correct position of that comet's radiant-point. The error of the radiant-place was noticed immediately after the presentation, but not in time to prevent its publication in the paragraphs of the Report of the year 1878. The correction which the above passages required was accordingly pointed out in a 'Report on Meteoric Astronomy during the year 1878,' presented to the Royal Astronomical Society in February, 1879 ('Monthly Notices,' vol. xxxix. p. 294). Dr. J. L. E. Dreyer, of the Dunsink Observatory, Dublin, who has devoted much attention to the orbit of this comet, has noticed that the true astronomical place of its meteor radiant-point (which he gives at 27° 51′ + 48° 24′) is in pretty good agreement with a meteor system nearly contemporaneous with the Perseïds, noted by Schmidt

Errata—continued.

Page	Line	Corrections and Remarks
		and others near χ Persei.[1] Of this radiant-point a conspicuous maximum or special meteor-shower has been detected by Mr. Denning on July 31, 1878, and it is with these meteors or with the Perseïds II. forming as distinct a special meteor system at the beginning of August as the Lyrids and Geminids are in April and December, and not at all with the ordinary August Perseids I. that Dr. Dreyer supposes the comet 1870 I. to be very possibly connected.]
353	4.	*For* Beiner *read* Einer.

Errata for correction in the Volume of these Reports for the year 1879.

Page	Line	Corrections and Remarks
80	23 and 22 from foot.	*Insert* comma *and* semicolon *after* air *and* simultaneously. [Dr. Cleveland Abbé has by a recent letter reminded the Committee that the explanation here given of meteoric sounds has originated from his own propositions, and was not embraced with any special application to such a question in the general theory of sound and light waves treated of in the paper by von Eotvos.]
,,	4 from foot.	*For* Appomatox *read* Appomattox.
82	19.	*For* meteors *read* meteor.
,,	Last line.	*Add to the Note* 'Meteor Notes for Jan., 1879.' by W. F. Denning.
86	2 et seq.	*Enclose in square brackets the words* The elements, &c., *and the column of* elements of Biela's comet.
88	30.	*After* 1680 and 1833, *add* The closest approach of the latter comet's to the earth's orbit occurs on Jan. 27, with a radiant-point at 135° + 25°.
99	11 from foot.	In the column 'Appearance, &c.,' of the meteor seen at Writtle, *insert* (see Mr. Corder's supplementary meteor list, *inf.*, p. 114.)
100	10.	*After* Thames Embankment, London, *add* [and at Chelmsford.] In the column 'Appearance, &c.,' of the same observation *add* [see Mr. Corder's list, *inf.*, p. 114.]
102	12 from foot.	*For* '3 or 4 seconds, &c.' *read* '3 or 4 seconds,' &c.
103	12.	In the column 'Observer, &c.,' *for* Indianopolis *read* Indianapolis.
105	19.	In the column 'Appearance, &c.,' *after* heard in 2^m *add* At Stockton very violent, causing terror and affright.
,,	24 from foot.	*For* J. W. Backhouse *read* T. W. Backhouse.
108	24 from foot.	*For* 1858, Aug. 13, [True time 6.39 p.m] *read* Autumn of 1863 or 1864. [Probably 1864, Nov. 11.] [True time probably 5.35 p.m.] In the same observation, column 'Colour,' *for* [streak white ?] *read* The long streak white.
109	15 from foot.	*For* [Seen also, &c....] *read* [The same as that seen in France and Kent; these Reports vol. for. 1865, pp. 78, 120. Radiant at 85 + 35 (± 10°).]

[1] *Astronomische Nachrichten*, vol. lxxxii. No. 1963; and *Proceedings of the Royal Irish Academy*, 2nd ser. vol. iii. (Science), p. 255.

Errata—continued.

Page	Line	Corrections and Remarks
110	26 from foot.	*For* Rubernpré *read* Rubempré.
111	26.	Column 'Appearance, &c.,' *after* Paris *at end of the description, add* No detonation seems to have been heard.
114	10.	*After* Chelmsford add [seen also in London; see the above General List.]
116	5.	*Dele* 1858, Aug. 13, $6^h 39^m$ p.m., &c., *striking out the whole* of this first accordance of the List. See the *Note* in the *Erratum* of p. 120.
,,	11.	*After* (Berne time) *add* A fine fireball; long, slow flight, as if impeded, but uniform in brightness up to sudden disappearance. White, yellowish, or pinkish, with tail of fading sparks, and some light-streak left upon its course. No detonation heard.
117	11.	In column of 'Remarks' *add* [Calculation of the meteor's real path by G. von Niessl; 'Verhandlungen des Naturforschenden Vereins in Brünn,' Bd. xvii.]
,,	17.	Column of 'Remarks' *for* Dec. 27 *read* Denning 27.
,,	16 from foot.	Column 'Observed Radiant,' *after* χ Ursæ Majoris, *add* The three observed paths emanate very nearly from one point.
118	5 from foot.	Column 'Places of Observation,' *after* Dundee, &c., *add* Several good accounts of the meteor collected and reduced by J. E. Clark.
119	27.	Column of 'Remarks' *for* Dec. 2, 1877, *read* Denning 2, 1877.
,,	33.	Column 'Observed Radiant-point,' *for* 47° *read* 55°.
,,	34.	Column 'Length of Path,' &c., *after* estimated; *add* but the observations indicated a rather slow motion.
120	18.	1858 Aug. 13 $6^h 39^m$ p.m. *et seq. to end of* the paragraph on p. 46, *dele* all the Remarks on this accordance, which is a mistaken and unreal one; and append the following *Note*:—Oct., 1879. A letter just received from Mr. Caws states that the meteor which he saw near Ryde was certainly observed in the autumn of one of the years 1863 or 1864, and not, as his original description seemed to intimate, in the year of Donati's comet, 1858. The fireball which it described was doubtless the grand one which at dusk on the moonlit evening of Nov. 11, 1864, passed over the southern part of France, and which was pretty widely observed there, and in Kent (see these Reports, vol. for 1865, pp. 78, 120). The contemporary descriptions, with the addition of this new one, only allow the real path to be roughly assigned (as follows) as a good average combination of the plentiful but loose materials. The meteor began its flight 70 or 80 miles above the neighbourhood of Macon, or of a point mid-way between Lyons and Clermont, and passing in mid-path over the southern part of the mountains of Auvergne, ended its course about 50 or 60 miles above a point mid-way between Cahors and Montauban, on the rivers Lot and Tarn. The whole distance of 150 or 200 miles was traversed in about 5 seconds, with a speed of about 35 miles per second, from the direction, roughly, of a radiant-point at about alt. 5° or 10°, in the N.E.; celestial position 85° + 35° (± 10°.) The parabolic speed of a meteor with this radiant-point is 32·5 miles per second. A bright streak visible in the twilight sky (at Rhodez, and at Pamiers in Arriège) for several minutes, when the nucleus broke up rather suddenly at last, remained along its course like an after-glow of the splendidly luminous white tail, similar in brightness to the head, by which the nucleus was pursued. Its appearance, although extremely brilliant, eclipsing the full moonlight at Rhodez and other places near its path, was unaccompanied by any audible report.

E 2

Errata—continued.

Page	Line	Corrections and Remarks
121	5.	1877, Oct. 8–9, midnight. To this accordance append a *Note.* The accordance is illusory. Mr. Denning's observation in England was made 13^m earlier than that noted in France and Belgium.
"	17.	*For* radiant-points *read* radiant-point.
122	2 from foot.	*For* Museids *read* Muscids.
124	Wood-cut.	In the Illustration 'Radiants of Geminids,' *erase* from the figure the shaded area, which was not intended to appear in the engraving.
125	16.	*For* torilite *read* troilite.
128	20.	*For* material *read* meteorite.

APPENDIX II.—*Aërolites. By* WALTER FLIGHT.

1841, *September* 6.—*St. Christophe-la-Chartreuse, Commune de Roche-Servières, Vendée.*[1]

The fall of this stone, which was accompanied by a double detonation resembling thunder and a luminous appearance, took place in the vineyards of St. Christophe at the above date. It created quite a panic in the surrounding country; on the first day none of the peasants would approach it; one could only look with fear in the direction where it lay, it was said; but on the following day a young man, who was escorted to the spot, found it out and brought it away with him.

The stone weighs 5·500 kilogrammes, and is in the hands of a proprietor who was neither disposed to communicate any information respecting it, nor to allow any fragments to be removed. M. Daubrée has therefore to content himself with registering its existence, which up to the present time has not been placed on record.

1874, *November* 26, 10.30 *a.m.*—*Kerilis, Commune de Maël-Pestivien, Canton de Callac* (*Côtes-du-Nord*).[2]

A great noise, lasting two minutes and resembling a peal of thunder, was heard at this date at Maël-Pestivien and for ten kilomètres around. At the same instant a workman near the village of Kerilis saw the earth struck, at a spot 12 mètres distant, by what he believed to be thunder. He visited the spot the next day, and found a meteorite at a depth of 0·78 mètre. The stone weighed 5·000 kilogrammes, and is covered with a remarkably thick black crust: a number of fragments were detached from the stone till its weight was reduced to 4·200 kilogrammes; it then passed into the hands of a clergyman, who bought it and presented it to the Natural History Museum of Paris.

A freshly broken surface of the stone shows a mottled and striated surface, with metallic grains of nickel iron; the surface is of a deep gray colour with ochre-coloured spots, due doubtless to traces of iron chloride. The individual grains vary in size; some, the largest, are chalk-white,

[1] M. Daubrée, *Compt. Rend.*, 1880, xci. p. 30. [2] *Ibid.*, p. 28.

the most numerous are of an ashy-gray; here and there rounded grains (the chondra of Gustav Rose) are apparent, as well as yellow or bronzy grains of pyrrhotine. The grains of nickel iron are very small. The density of the meteorite is 3·51. By the action of hydrogen chloride 60 per cent. of the stone dissolves: this consists of olivine, nickel iron, and pyrrhotine; the residue under the microscope is found to consist of a great number of crystalline grains, much acted upon by polarised light, and some of which show the forms of the prism; others show the cleavage which indicates enstatite. Besides these are black grains of chromite with an octahedral contour.

This stone most closely resembles those of Limerick (Adare) which fell 1813, September 10th, and Ohaba, Siebenbourg, 1867, October 10th, and belongs to the group of Sporadosideres and the sub-group Oligosideres.

1879, *May* 10, 5 *p.m.*—*Estherville, Emmet Co., Iowa.*[1]

This curious meteorite fell near Estherville in lat. 43° 30′ N., long. 94° 50′ W. within that region of the United States which has been remarkable for falls of meteorites, three having fallen at Rochester in Indiana, Cynthiana in Kentucky, and Warrington in Missouri, within the space of a month. The phenomena attending this fall, of which a short notice appeared in the Report of last year, were of the usual character, but on a grander scale. It occurred about five o'clock in the afternoon of May 10, 1879, with the sun shining brightly. In some places the meteorite was plainly visible in its passage through the air, and looked like a ball of fire with a long train of vapour or cloud of fire behind it; and one observer saw it one hundred miles from where it fell. Its course was for N.W. to S.E. The sounds produced in its course are described as being 'terrible' and 'indescribable,' at first louder than the loudest artillery, followed by a rumbling noise, as of a train of cars crossing a bridge. Two persons were within two or three hundred yards of the spots where the two larger masses struck the earth. There were distinctly two explosions: the first took place at a considerable height in the atmosphere, and several fragments were projected to different points over an area of four square miles, the largest going farthest to the east. Another explosion occurred just before reaching the ground, and this accounts for the small fragments found near the largest mass. This latter fell within 200 feet of a dwelling-house, at a spot where there was a hole, six feet deep, filled with water. The clay at the bottom of the hole was excavated to a depth of eight feet before the meteorite was reached. The second largest mass penetrated blue clay to a depth of five feet, at a spot about two miles distant from the first. The third of the larger masses was found on the 23rd February of the present year at a place four miles distant from the first, in a dried-up slough. On digging a hole the stone was met with at a depth of five feet. The fragments thus far obtained weigh respectively 437, 170, 92½, 28, 10½, 4 and 2 pounds. The height of the meteor is calculated to have been 40 miles, and its velocity from 2 to 4 miles per second. The masses are rough and knotted, like large mulberry calculi, with rounded protuberances projecting from the surface on every side. The black coating is not uniform, being most marked between the projections. These projections have sometimes a bright metallic surface,

[1] J. L. Smith, *Amer. Jour. of Sc.*, June 1880, xix. 459.

showing them to consist of nodules of iron; and they also contain lumps of an olive-green mineral, having a distinct and easy cleavage. The greater part of the stony material is of a grey colour with the green mineral irregularly disseminated through it. The masses vary very much in density in their different parts; the average cannot be less than 4·5. When a mass is broken one is immediately struck with the large *nodules* of metal among the grey and green stony substance; some of these will weigh 100 grammes or more. In this respect this meteorite is unique; it differs entirely from the siderolites of Pallas, Atacama, &c., or the known meteoric stones rich in iron, for in none of them has the iron this nodular character. The large nodules of iron appear to have shrunk away from the matrix; an elongated fissure of from 2 to 3 millimètres sometimes intervenes, separating the matrix and nodules to the extent of one-half the circumference of the latter. The only mineral which could be picked out separately has a slightly green colour: it occurs in masses, from one half-inch to one inch in size, has an easy cleavage in one direction, and was found to be olivine. The same mineral occurs in minute rounded condition in other parts of the material; and minute, almost colourless, crystalline particles in the cavities are supposed to be olivine. Troilite exists in small quantity. A quantity of the silicates was picked out, separated as far as possible from iron, and treated with hydrochloric acid. The ratio of soluble to insoluble silicates varies very much in different parts of the meteorite, varying from 16 to 60 per cent. for the soluble part. The insoluble consisted of:—

		Oxygen.
Silicic acid	54·12	29·12
Iron protoxide	21·05	4·67
Chromium oxide	trace	—
Magnesia	24.50	9·80
Soda with traces of K and Li	·09	0·023
Alumina	·03	0·013
	99·29	

This is evidently the bronzite commonly found in meteorites.

The green mineral is the soluble part of the meteorite; its cleavage in one direction is very perfect; its specific gravity is 3·35; it has a hardness of almost 7, and is readily and completely decomposed by hydrochloric acid. On analysis it was found to have the composition:

		Oxygen
Silicic acid	41·50	22·13
Iron protoxide	14·21	3·12
Magnesia	44·64	17·86
	100·35	

The mineral, therefore, is olivine. Dr. L. Smith, who has examined this meteorite, describes a third silicate which is opalescent and of a light greenish-yellow colour, and cleaves readily. It was a difficult matter to obtain enough of the silicate for analysis, but an examination of 100 milligrammes gave the following numbers:

Silicic acid	49·60	26·12
Iron protoxide	15·78	3.50
Magnesia	33·01	13·21
	98·39	

This is equivalent to one atom of bronzite and one atom of olivine, which, he says, is 'a form of silicate that we might expect to find in meteorites.' The nickel iron, as has already been stated, is abundant, sometimes in large nodules of from 50 to 100 grammes. It displays the Widmanstättian figures beautifully, and possesses the following composition:

Iron	92·001
Nickel	7·100
Cobalt	0·690
Copper	Minute quantity
Phosphorus	0·112
	99·903

A careful examination for felspar and schreibersite was made, but with a negative result.

Found 1879, *July* 19.—*Lick Creek, Davison Co.*[1]

In this paper is given an engraving, actual size, and a short account of a small metallic mass, weighing rather more than two pounds, and found at the above date in Davison county. When found it was covered with a thick scaly crust of oxide. It weighs 1·24 kilogrammes or 23¾ ounces avoirdupois. It is one of the rare class that do not show the Widmanstättian figures. It contains iron, nickel, cobalt, and phosphorus. A complete analysis of the meteorite is being prepared. It is the property of Prof. W. E. Hidden, of the New York Academy of Sciences. Mr. Hidden has in his cabinet three other undescribed meteorites from the Southern States, one of which weighs 1·45 kilogrammes, or 32½ oz. avoirdupois.

1880, *February* 18, *early in the Morning.—Kuritawaki-mura, Yosa-no-gori, Tango, Japan.*[2]

An eye-witness of the fall of this stone states that in the early morning he was washing his face, when he saw a ball of fire cross the sky from north-east to south-west. He was much astonished when a small stone fell before him from the sky. He caught it up and found it was very hot, and gave forth a smell like that of gunpowder. The stone is about 1½ inches long and three-quarters of an inch wide, and weighs about 100 grains, Troy. It is completely covered with a hard black glaze. It appears to be a stone and not meteoric iron.

The same correspondent mentions a meteoric stone of large size, preserved at Toji, which is said to have fallen from the heavens in ancient times; and reports another at Chionin. He also says: 'I learn that a stone of several pounds weight fell at Tamba a few years ago.'

The same number of the 'Japan Gazette' contains a short reference to another aerolite. The mineral stone which fell some time ago at the front of a gate of Iwata, of Takeda-mura, Yabe-gori, Tajima, with a brilliant light and report, is about 1½ *sun* thick and 9 *sun* in circumference, and weighs about 200 *momme.* This stone has been sent to the Bureau of Agriculture of the Home Department, and will be investigated by Prof. Kinch.

[1] *Illustrated Scientific News*, New York, March 15, 1880, iii. No. 6, pp. 62 and 66.
[2] *The Japan Gazette*, April 19, 1880.

First and Second Reports of the Committee, consisting of Mr. DAVID GILL, Professor G. FORBES, Mr. HOWARD GRUBB, *and* Mr. C. H. GIMINGHAM, *appointed to consider the question of Improvements in Astronomical Clocks.*

First Report. By Mr. DAVID GILL.[1]

To maintain the motion of a free pendulum in a uniform arc, when the pendulum is kept in uniform pressure and temperature, and to record the number of vibrations which the pendulum performs, is to realise the conditions which constitute a perfect clock.

The conditions of absolute uniformity of impulse are, *with one exception*, realised in the following arrangement.

Let S (figs. 1, 2, 3) be the point of suspension of a pendulum, and P, in the same figures, the pendulum rod.

FIG. 1.

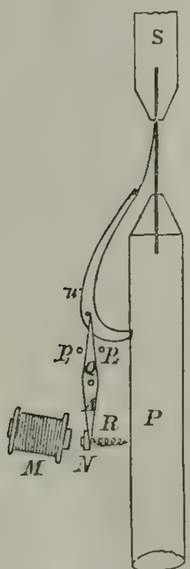


FIG. 2.

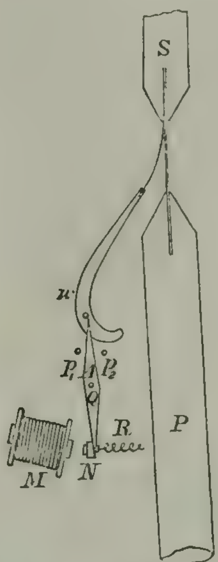
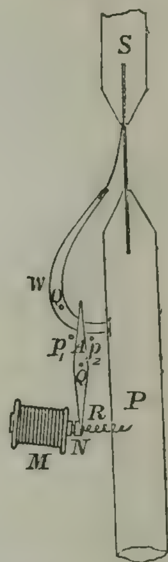


FIG. 3.



Let W be an impulse-piece of the shape shown, suspended by a piece of very delicate spring, so as to swing accurately from the same centre as the pendulum.

M is an electro-magnet, N an armature mounted on an arm A, which is pivoted at Q.

In fig. 1 the pendulum is supposed at rest; but the armature N, and the arm A are drawn, as they cannot remain, for A must either be pulled against the backing pin p, by the spiral spring R, or against p_2, by the attraction of the electro-magnet M.

Let us now suppose that matters are so arranged that when the impulse-piece W acts upon the pendulum, a galvanic circuit is completed, and M becomes an electro-magnet, we shall then have the position of the arm A, and of the impulse arm W, as in fig. 3, and when the impulse weight and pendulum rod are separated, we shall have the position of these as shown in fig. 2.

[1] Read at the Sheffield Meeting, 1879, but omitted from that year's Report at the author's request.

Now let us follow the action of this escapement.

First suppose the battery to be attached when matters are in the position shown in fig. 1. The effect will be that the arm A will be drawn against p_2. If we now set the pendulum swinging to the right the impulse arm W will follow the pendulum as far as the arm A will allow it to do so, but on reaching this limit, the pendulum will leave the impulse arm and continue to swing to the right alone.

The instant, however, that the contact between W and P is thus broken, M is no longer an electro-magnet, and the arm A is drawn by the spiral spring to the position of fig. 2; the pendulum continues its swing to the right, comes to rest, and returns. On its return it encounters the impulse-piece W, *not* where it left it (viz., at its lowest limits, the arm A resting on p_2), but as in fig. 2, the arm A resting on p_1. When P and W encounter, the immediate result is that, contact being formed, M becomes a magnet, and the arm A is drawn against p_2, whilst the impulse-piece W continues its motion towards the left, along with the pendulum, and returns again to the right with the pendulum till it is stopped by encountering the arm A pressing against p_2.

Simply stated, the impulse is this:—The pendulum in swinging *against* the impulse-weight picks it up at p_1, and in swinging *with* the impulse-weight it carries it on past p_1 as far as p_2. The effective impulse is, therefore, that of the fall of the resolved horizontal force of W in falling from p_1 to p_2.

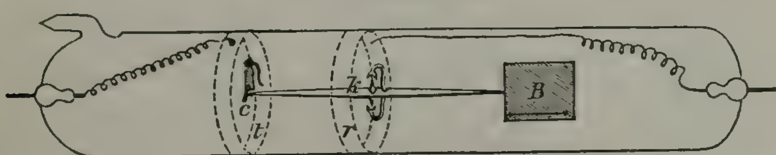
This force is absolutely constant.

There is no locking or unlocking, and no friction, and *no element of change except such as may be due to the electric contact between* W *and* P. Such contacts are liable to wear and to stick, and it was not until some prospect offered of overcoming this fault that we ventured to request a grant from the Association. The plan of escapement had already been contrived and tried experimentally by Mr. Gill; but it was in consequence of an idea of Mr. Gimingham's that it first seemed possible to overcome the outstanding difficulty and attain a nearer approach to perfection.

Mr. Gimingham's idea was to construct a relay which could be worked by radiation. This relay he first contrived for the purpose of registering the number of revolutions of a radiometer.

The form which this relay has now assumed, after a variety of experiments, is shown in fig. 4.

FIG. 4.



K is a very light arm of aluminium, mounted on needle-points.

B is a fan of mica, coated on one side with lampblack.

C is a carbon point attached to K.

By means of an aluminium ring r, fitting spring-tight into a glass tube, the supports of the needle-points of K are fixed in position—the supports being attached to the ring.

Another ring, t, carries a small carbon anvil, against which the carbon point C can come in contact.

Two platinum wires, in connection with r and t respectively, are fixed into opposite ends of the tube.

The tube is then exhausted till a Crookes' vacuum is obtained, when the arm K becomes a radiometer arm.

A small slip of magnetised watch-spring is attached to B, so that a fixed magnet can be so placed as just to bring the carbon point and anvil in direct contact.

A strong light being then turned on B, the screen acts like a radiometer arm, moves back, separates the carbon points, and contact is broken.

By attaching a simple screen to the pendulum, it therefore becomes possible to cause the pendulum, by alternating, to admit and cut off light from B, and so produce alternate make and break, entirely as required by the escapement, without employing any actual contact on the pendulum.

The chief difficulty we now find is a tendency of the carbon points to stick, and some experiments are now being made relative to this matter.

Four relays on the principle described have been constructed and are in the hands of the committee for experiment, and Mr. Gill has, besides, a model of the escapement, and a pendulum with which experiments are being carried out.

A sum of 12*l*. 12*s*. has been expended out of the grant of 30*l*., and the Committee requests that the balance of the grant should be allowed to be applied to the same research.

Second Report.

Since the foregoing report was sent from the Cape by Mr. Gill, I have devoted much time in developing the mode of electric contact-making by radiation.

In the above report for last year is described a form of the radio-relay which at the time seemed to give the most promising results of any that I had tried. Four of these were made, as mentioned by Mr. Gill, one of which he took out to the Cape, experimented with, and in the report he mentions the chief difficulty as being that of the tendency of the contacts to stick together when work is being done by the current.

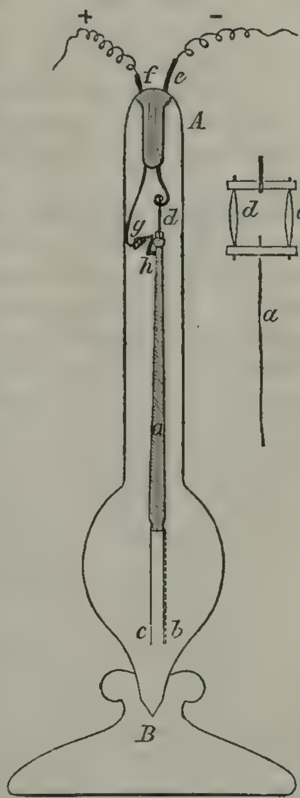
In the case of using contacts of metal, such as platinum, this difficulty is insurmountable, for the reason that the power required to separate the contacts when once closed is far greater than that which can be obtained from any source of radiation that could be used for our purpose. This point I had settled some time back, and had almost abandoned the idea of success, when the discovery of the microphone by Prof. Hughes suggested to me the idea of using carbon contacts. I then commenced working on the subject again, and experimented with a great number of instruments of different forms.

The form of a pendulum with the contacts near the point of suspension has at present given the most satisfactory results. Fig. 5 represents the pendulum form of the radio-relay; a is a strip of moderately thin aluminium, to the lower end of which is attached a plate of silver flake mica b, blackened on the outer face; c is a clear mica screen, the same size as the plate b, also attached to the lower end of a, enclosing a space of about 6 mm. between the two plates.

The strip of aluminium a is suspended by two springs of soft iron wire, beaten out flat and very thin in the centre, represented by d in

section and $d\,d'$ in elevation. The springs are in metallic connection with the platinum wire e, which is hermetically sealed through the tube A. To the other platinum wire f, the inner end of which is beaten out into a thin spring, is attached a carbon point g, h being the corresponding carbon plate attached to the pendulum, just below the suspension springs. The whole is enclosed in the tube A, which is expanded into a bulb at the lower end, exhausted from the end B, and hermetically sealed.

Fig. 5.



On placing a source of radiation in front of the blackened surface b, and allowing a screen to move to and fro between the source of radiation and the bulb, contact will be alternately made and broken between the *carbons* g and h. In order to give an idea of the amount of radiating force required to produce a Crookes' pressure of sufficient power to work an instrument of this kind, I will mention that a candle placed four or five inches off the bulb, with a concave reflector at the back, answers exceedingly well, providing the surface b is about $1\frac{1}{2}$ square inch in area. The actual effective force also depends to a great extent upon the distance between the surface b and the glass envelope. For this reason I have tried using a clear mica screen, placed inside the bulb very close to the black surface; but although theory would indicate the advisability of so doing, practice shows that very little advantage is gained by the introduction of such a screen, the fact being partially accounted for by its forming a second obstruction to the radiant force from the light used to work the relay.

By the introduction of carbon contacts I had hoped to have entirely avoided their sticking together when the current passed. Although for all practical purposes their employment together with the pendulum form of instrument has sufficiently reduced this sticking, yet to a certain extent it still remains a drawback to the use of such a delicate force for making contact as that to be obtained from this indirect action of the radiation from a small lamp or candle.

When the contacts merely pass the current through a short length of straight wire, there is little or no sticking, but on the introduction of an electro-magnet, a bright spark passes between the contacts, and sticking occurs. The spark is well known to be due to the discharge of the extra currents set up in the coils of the magnet, and I expected that both the spark and the sticking would disappear on attaching a tin-foil condenser to the terminals of the relay. On trying this experiment the spark was reduced, but there was no observable alteration in the sticking.

This sticking is probably due either to the carbon containing a fusible ash, or the attraction caused by the close proximity of the two large surfaces of oppositely charged carbon, large compared with the part that absolutely touches and through which only part of the current would be

passing. I have tried several kinds of carbon for the contacts, but the finest electric-lamp carbon seems to be the only available sort, the resistance of more compact carbons being too high. I have also tried using contacts of platinum, iridium, also one of platinum and the other of gold, platinum and iridium, carbon and iridium, carbon and platinum, all of which stick together more than when both are of carbon.

In order to overcome the, for the present, inevitable amount of sticking of the carbon contacts, it is necessary to multiply the force for making and breaking contact by means of long leverage. It will be seen that in the pendulum arrangement described, any amount of leverage can be easily obtained without the friction or resistance that would be caused by pivots.

The force, also, obtainable from a given source of radiation, is greatly augmented in this instrument by the use of a screen placed a little distance behind the blackened surface, but fixed to it as part of the pendulum bob. In this way nearly the maximum amount of Crookes' pressure is obtained, all acting in the one direction, whereas, if there be no screen behind the black surface, the heat transmitted through the blackened mica sets up a considerable Crookes' pressure, which acts between the bulb and the back of the blackened mica, considerably reducing the effective force in front.

In experimenting with these various radio-relays, I have used a seconds pendulum, having an escapement similar to that described by Mr. Gill in his report for last year.

It has been necessary to use an ordinary, but very sensitive, relay between the radio-relay and the pendulum, as it is best to have as weak a current as possible passing through the carbon contacts.

I regret that my experiments in the radio-relay part of the subject should have extended over such a long period, but the time I have at my disposal for original work is very limited.

I also regret that I cannot be present at the meeting this year, to show the various relays, and receive suggestions from the members of Section A. I shall, however, carefully study any discussion that may be recorded on the subject, and in the continuation of the experiments make use of any suggestions with great pleasure.

C. H. GIMINGHAM.

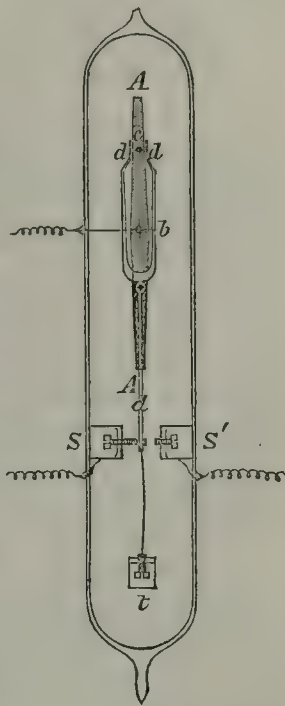
Dear Mr. Gimingham,—I return you herewith Mr. Gill's letter and diagrams. The principle of his proposed arrangement seems admirable, provided a perfect system of contacts could be devised, and your plan for them is unexceptionable in theory; but as it appears that the carrying out of the details may be a little troublesome, I have had recourse for the present to a more simple contrivance, which, though not so perfect theoretically, will, I believe, be found to work very well in practice.

I annex a figure (fig. 6) which represents the arrangement. A very small magnetised needle A A is pivoted as a compass needle on a vertical pin *b*. In a plane above or below this is pivoted a light forked lever *d d d* so placed that a pin *c* in the magnetised needle, hits one or other of the prongs of the fork *d d* as it swings from side to side. At the extreme end of the lever *d* is fixed a fine fibre of spun glass slightly buckled by the screw *t*; this has the effect of putting the forked lever *d d* into a state of unstable equilibrium and compelling it to keep in contact with one or other of the contact screws S S′. The whole apparatus is enclosed in an

exhausted glass tube (to prevent oxidation of the gold contacts) and when required for use is placed in the clock case just below the iron 'bob' of the pendulum.

As the pendulum swings the magnet answers to its motion and draws the forked lever into contact with either of the screws s s′ which are tipped with gold. The buckling of the glass fibre tends to make the contact very certain and avoids any danger of recoil, while there being no oxygen left in the tube there can of course be no oxidation of the contacts.

Fig. 6.



It is supposed that the clock has a mercurial pendulum with cast-iron cistern, as most pendulums are now made.

The above arrangement is not theoretically perfect, for there must of course be some slight reaction from the magnet to the pendulum; but as the pendulum weighs, or should weigh, about forty pounds and the magnet about ten grains, the reaction must be very slight, and even this would be of no consequence provided the magnetisation of the needle remained constant.

The convenience of the arrangement, and the ease with which it can be applied without interfering or tampering with the clock, commends it for practical work.

The only practical fault I see in Mr. Gill's arrangement for *driving* the pendulum, is the extremely small 'travel' which the impulse lever has in each impulse. This will necessitate very perfect 'banking' arrangements, for a very small difference in this travel will make a large difference in the impulse on the pendulum, and the perfection of the arrangement depends on the impulse being a constant. It appears to me that it would be desirable to make the impulse-arm very light, but longer in its travel, and acting perhaps farther down on the pendulum rod.

These are the only points that occur to me.

Faithfully yours,
HOWARD GRUBB.

Dublin: August 23, 1880.

Report of the Committee, consisting of Professor Sir WILLIAM THOMSON, Professor TAIT, Dr. C. W. SIEMENS, Mr. F. J. BRAMWELL, *and* Mr. J. T. BOTTOMLEY (*Secretary*), *for commencing Secular Experiments on the Elasticity of Wires.*

THE Committee have but little to add to their reports of the last years. The arrangements in the tower of Glasgow University may now be regarded as complete, so far as concerns the wires already suspended there for experiment. At the last meeting of the Association it was reported that pairs of wires of gold, platinum, and palladium had been

suspended in the tube provided for their protection, and that they had been carefully marked and measured. Since the last meeting observations have been made at intervals on the lengths of the wires, and these have been carefully recorded. It cannot be said that there has been any perceptible lengthening of the wires within the last year.

Some improvements have been made as to caulking the joints of the protecting tube in order to avoid disturbance of the wires by currents of air.

A set of drawings, showing the mode of suspension of the wires, the marks that have been put upon them, the arrangements of the cathetometer, &c., in such a way as may be useful for reference at any future time, is nearly ready, and will be published in next year's Report.

Sixteenth and concluding Report of the Committee, consisting of JOHN EVANS, *F.R.S.*, Sir JOHN LUBBOCK, *Bart.*, *F.R.S.*, EDWARD VIVIAN, *M.A.*, GEORGE BUSK, *F.R.S.*, WILLIAM BOYD DAWKINS, *F.R.S.*, WILLIAM AYSHFORD SANFORD, *F.G.S.*, JOHN EDWARD LEE, *F.G.S.*, *and* WILLIAM PENGELLY, *F.R.S.* (*Reporter*), *appointed for the purpose of exploring Kent's Cavern, Devonshire.*

YOUR Committee's last, or fifteenth report, read during the Sheffield Meeting in 1879 (See 'Report Brit. Assoc. 1879,' pp. 140–148), brought up the narrative of the exploration of the Cavern to the end of the preceding month. From that date to 27th November, 1879, the work was continued day by day, in the manner adopted at the beginning and described in previous reports.

Visitors.—The Superintendents have again had the pleasure of receiving numerous visitors, and, whilst conducting them through the principal portions of the Cavern, of explaining to them the most important and striking discoveries made during the progress of the work. The following gentlemen, accompanied in most cases by ladies, may be mentioned as amongst the visitors received:—Sir J. Bain, Sir C. A. Hartley, Revds. Preb. R. R. Wolfe, Dr. J. Baron, W. Earle, W. J. Earle, and J. H. N. Nevill; Captain Mackenzie; Drs. A. Davidson, H. S. Gaye, T. A. Hirst, J. S. Phené, and H. C. Sorby; and Messrs. S. Bompas, C. S. M. Bompas, H. B. Bompas, B. V. S. Brodie, H. Burlingham, N. Cole, W. R. Cole, H. H. P. Cotton, A. De Lisle, E. M. Grant Duff, C. Earle, S. Farnfield, A. L. Fox, C. Freeman, W. H. E. Gaye, A. C. Haddon, T. Heath, W. H. Holder, C. H. S. Hope, A. N. Johnson, R. I. Johnson, H. B. Mackeson, E. R. Pease, J. G. Pease, A. Perks, J. Perks, W. Perks, E. J. Sing, A. E. Sorby, W. Spriggs, A. E. Tylor, T. Viccars, G. F. Whidborne, F. R. Wildon, W. M. Williams, E. T. B. Wilson, J. H. Wilson, and J. W. Wilson.

The Rocky Chamber.—Your Committee, describing in their last report that portion of the Cavern termed 'Clinnick's Gallery,' remarked: 'On its eastern side, the third or innermost reach of Clinnick's Gallery opens into a large chamber, which the workmen have just begun to

explore.' ('Rep. Brit. Assoc.' 1879, p. 147.) This portion, now known as 'The Rocky Chamber,' is 56 feet long, about 28 feet in greatest breadth, and about 13 feet in greatest height, which it attains near the centre. It is ornamented with numerous striking stalagmites and stalactites, though less profusely than the two small adjacent chambers described last year (*Ibid.*) These have been left intact so far as possible, and will, no doubt, in future render this Chamber the most attractive part of the Cavern to ordinary visitors.

The deposits in the first or western part of the chamber were the well-known 'Breccia,' or oldest of the Cavern beds, with its characteristic 'Crystalline Stalagmite' overlying it immediately. Each of these 'thinned out' entirely before the centre of the Chamber was reached, and the bare limestone floor lay exposed for a distance of 18 feet. Beyond the centre another deposit presented itself, differing in character, not only from the Breccia, but also from the less ancient 'Cave-earth,' being more like the ordinary soil of cultivated ground, than either of them; there is no doubt, however, that it belonged to the Cave-earth era. It was at first but a very thin layer, covered uniformly with a sheet of 'Granular Stalagmite,' no more than a few inches thick; but, as the work advanced eastward, both the stalagmite and the deposit it covered became gradually thicker, never, however, attaining a depth of four feet, so that the limestone floor of the Cavern was laid bare in every section.

In the right wall as one enters the Chamber, and about midway in its length, there is a very narrow crevice or slit in the limestone extending obliquely from the roof to the floor. It contained no mechanical deposit of any kind; but what may be called its lower wall was lined with a thin sheet of stalagmite.

The exploration of the Rocky Chamber occupied about four months, but the labour was not repaid with the discovery of any specimen of much value. It is satisfactory, however, to have certainly ascertained whether or not the deposits there contained anything of interest. The 'finds' met with were only five in number (Nos. 7,318 to 7,322), and may be briefly described as below:—

No. 7,318. Part of the skull of a large Hyæna, and a detached left upper sectorial tooth belonging to the same species, probably the same individual; found in contact with the bottom of the Granular Stalagmitic Floor, September 12, 1879.

No. 7,319. Relics of Hyæna, consisting of the right upper sectorial tooth; the molar immediately in front of it; the crown of a canine tooth, the three upper left incisors still in part of the jaw; the right outer upper incisor; and a fragment of skull. The whole were found on September 16, 1879, at the bottom of the Granular Stalagmite, and were not improbably portions of the individual represented by the 'find' No. 7,318, from which they were about two feet distant. No. 7,319, however, included a few fragments of bone belonging to some smaller species.

No. 7,320. A piece of flint of nondescript form, from which several flakes had been dislodged. It was 2·4 inches long, 1·75 inch in greatest breadth, 1 inch in greatest thickness, unrolled, the edges tolerably sharp, apparently non-utilized, and having a chalky texture. It was found in the fourth foot-level below the Granular Stalagmite, without any object of interest near it, on September 25, 1879.

No. 7,321. Skull of Sheep, with eight teeth, and an axis of probably

the same individual. Found November 27, 1879, lying on, but unattached to, the sheet of stalagmite in the wall-crevice or slit mentioned above.

No. 7,322. The two rami of lower jaw of Wolf (?) or Dog (?), found November 27, 1879, embedded in, but not covered with the sheet of stalagmite in the wall-crevice or slit mentioned above. One of them was lying across the other, and together they contained twelve teeth, most of them worn considerably.

Second, that is deeper, Excavation, in the Long Arcade.—When the Committee began the exploration in March 1865, it was decided to make a first excavation from end to end, limited everywhere to the depth of 4 feet below the bottom of the Stalagmitic Floor; on the completion of this, to begin, at the entrance where ground was first broken, a second, that is a deeper excavation, and proceed in the same order as before through the entire Cavern. The first or 4-feet excavation was completed on November 27, 1879, when the exploration of the Rocky Chamber was finished. Every chamber, and gallery, and recess large enough for a man to work in—several of which had been discovered during the progress of the work—had been thoroughly excavated and explored, and the entire extent and character of the Cavern to the depth just mentioned, was perfectly known to the Superintendents, as well as to the workmen.

Excepting the Rocky Chamber and portions of one or two small narrow recesses, a limestone floor had nowhere been reached by the excavators, so that it was impossible to say what was the extent and character of the Cavern at lower depths, or what might be contained in the deposits still occupying them.

The Committee had by no means lost sight of the original idea of a second, that is deeper, excavation; nor were they unmindful of the fact that the work would be incomplete without it; but, bearing in mind that the exploration had already absorbed the continuous daily labour of nearly sixteen years, at a cost to the funds of the Association of 1,850*l.*—a result greatly in excess of the first rough estimate—they came reluctantly to the conclusion, during the meeting at Sheffield in 1879, that the time had very nearly arrived for closing the work, and that they would apply for but one further grant of no more than 50*l.*, with the definite statement that it was 'for the purpose of *finishing* the exploration.'

Though the Geological Section, to which it was at once communicated, acquiesced in this conclusion, it called forth a strong and general expression of opinion that it was eminently desirable to lay bare the limestone floor in at least some part of the Cavern, as well as to ascertain whether or not the large mass of deposit still unexcavated contained any animal relics or human industrial remains; and Professor W. C. Williamson, of Owens College, Manchester, suggested that subscriptions from private sources might not improbably be made so as to carry on the work for at least one additional year; and he expressed the hope that the suggestion would be kept in mind by the members of the Section, so that it might have some practical issue at the meeting of the Association, at Swansea, in 1880.

As soon as the entire 4-feet excavation was finished, the Superintendents, having a small portion of the 50*l.* grant still in hand, resolved to begin the deeper work, and for that purpose they selected a spot a little within the outer or northern end of 'The Long Arcade' (see 'Reps. Brit. Assoc.' 1872, pp. 44–47; 1873, pp. 198–207; 1874, pp. 3–6). This

spot had the advantages of being the lowest level reached in the previous excavation, of offering many facilities for carrying on the work, and the workmen would begin at once with the Breccia, or oldest known deposit, in the Cavern—all those of less antiquity having been there already removed. The work was begun on November 28, 1879, the workmen, as in the first excavation, digging their way daily farther and farther into the Cavern.

It having become known that only a very small sum remained in hand, the following subscriptions from friends at a distance, as well as in the neighbourhood, reached the Secretary from time to time :—

	£	s.	d.
Mr. G. W. Baker	1	0	0
„ A. Benas	0	10	0
„ B. Benas	0	10	0
Dr. Campbell Brown	0	10	0
Mr. I. I. Drysdale	0	10	0
„ H. Durander	0	10	0
Rev. W. Earle	1	1	0
Mr. M. Guthrie	0	10	0
„ I. W. Hayward	0	10	0
„ E. Hughes	1	1	0
„ A. R. Hunt	1	1	0
Mrs. A. Hunt	1	1	0
Miss Hunt	1	1	0
Mr. R. C. Johnson	0	10	6
„ Mr. W. Jones	5	0	0
„ W. Lavers	5	0	0
„ J. E. Lee (Member of the Cavern Committee)	3	3	0
„ R. Lowndes	1	1	0
Captain Mackenzie	5	0	0
Mr. Joseph Marples	0	10	0
Mr. Josiah Marples	0	10	0
„ W. Marples	0	5	0
„ Mr. G. H. Morton	0	10	6
„ C. G. Mott	0	10	0
„ Mr. W. H. Picton	0	10	0
„ Mr. D. Ratcliffe	0	10	0
„ I. Roberts (two donations)	6	3	0
„ J. T. Robinson	1	0	0
„ J. Samuelson	1	0	0
„ J. Tanner	0	10	0
„ Timmins	0	10	0
„ I. C. Thompson	0	10	0
„ E. Vivian (Member of the Cavern Committee)	2	2	0
„ Mr. G. Whidborne	1	0	0
Dr. G. F. A. Wilks	5	0	0
A Member of Torquay Natural History Society	1	0	0
Total	£51	10	0

The Committee take this opportunity to thank all the donors, and to express their sense of special obligation to Mr. Isaac Roberts, F.G.S., not only for his handsome donations, but for kindly interesting his friends in the work, as well as for receiving and transmitting their subscriptions.

The workmen were directed to carry the second, that is the lower, excavation to a depth of five feet below the bottom of the four-feet excavation, making a total depth of nine feet below the bottom of the Granular Stalagmitic Floor. The method of excavating employed from the first was still continued, the deposit being taken out in 'foot-parallels' and 'foot-levels' (See 'Report Brit. Ass.' 1865, pp. 19–20) ; a total length of 132 feet was excavated, in the first three of which a continuous limestone floor was laid bare ; beyond that it ceased, the limestone walls, instead of meeting actually, were separated by a longitudinal fissure varying from six inches to four feet, and averaging 1·75 foot in the first forty-five feet, but occasionally somewhat wider elsewhere. Throughout the greater part of the excavation a limestone floor was practically, though not actually, reached, the fissure being too narrow for the men to work. In this feature, as well as in some others, the Long Arcade closely resembled the two principal galleries of Windmill Hill Cavern, at Brixham, on the opposite shore of Torbay (See 'Phil. Trans.' clxiii. 485 ; or 'Trans. Devon. Ass.' vi. 798).

The deposit, with the exception of one or two small 'pockets' of Cave-earth, was everywhere the well-known Breccia. Stones rather

larger than usual were, perhaps, somewhat more than commonly prevalent in the lowest levels; but it still remains the fact that, so far as is at present known, the Breccia is the oldest deposit found in the Cavern. Pieces of Stalagmitic Floor, necessarily of still greater antiquity, presented themselves occasionally in the Breccia, a fact which had been frequently observed during the four-feet excavation; but no trace of the unbroken Floor whence they were derived has ever been detected.

On June 19, 1880, the Committee, having spent all the money placed at their disposal by the General Committee of the Association, as well as by their private friends, were under the necessity of suspending the work and discharging the workmen. Nearly seven months had been spent on the second or lower excavation, and though no more than eighteen 'finds' (Nos. 7323 to 7340) had been met with, the following description of them will show that the expenditure of time and money had not been quite in vain.

No 7323. A flint 'nodule-tool,' the butt end rudely an inequilateral quadrilateral, about 2·6 inches by 2·3 inches, and almost quite flat. When standing on this as a base, the tool may be described as an oblique triangular pyramid, its axis being at an oblique angle to the base. It attains its greatest girth about 1·5 inch above the base, where it measures 9·7 inches. The faces of the pyramid are by no means planes, and no two of them are of the same width. Their common vertex is a rather blunt edge about ·9 inch long, and their greatest widths 3·4 inches, 3·3 inches, and 1·5 inch. The extreme length of the tool is 5·9 inches. Portions of the original surface of the nodule remain almost everywhere around the butt end, and one face is completely covered with it except a space within 1·5 inch of the vertex, whence one flake has been dislodged. It was found alone, in the Breccia, in the eighth foot-level below the Granular Stalagmitic Floor, on December 11, 1879.

No. 7324. Two flint specimens (Nos. $\frac{1}{7324}$; $\frac{2}{7324}$).—No. $\frac{1}{7324}$ is a nodule-tool, almost white, and having no remnant of the original surface of the nodule. In outline it is rudely quadrilateral, about 2·1 inches long, the breadth at the ends being 1·2 inch and 1·1 inch; its greatest thickness is about ·7 inch, which it attains near the broader end. One face has a tendency to flatness, the other is convex, and has one principal longitudinal ridge, and two or three minor ones. No. $\frac{2}{7324}$ is a chip of but little interest. The 'find' occurred in the Breccia, in the fifth foot-level below the Granular Stalagmitic Floor, where it was met with on January 5, 1880.

No. 7325. A left last upper molar of Bear, a few pieces of bone, and a small flint chip; found in the Breccia, in the seventh foot-level below the Granular Stalagmitic Floor, on January 15, 1880.

No. 7326. A considerable portion of a rather large tibia, the distal end perfect, but the proximal end gone entirely. Found alone in the Breccia, in the seventh foot-level below the Granular Stalagmitic Floor, on January 20, 1880.

No. 7327. Crown of the tooth of Rhinoceros, found alone, in a 'pocket' of Cave-earth, on January 21, 1880.

No. 7328. A flint nodule-tool, 5·8 inches long, 2·7 inches in greatest width, and 1·7 inch in greatest thickness—the maximum width and thickness being about two inches from the butt end. It is very convex on one face, slightly so on the other, and has a small patch of the original crust of the nodule at the butt end. The opposite end is round-pointed, and

not more than ·2 inch thick. The tool was found alone on February 11, 1880, in the Breccia, in the eighth foot-level below the Granular Stalagmitic Floor. This specimen is peculiarly interesting, on account of a remarkably well-developed 'bulb of percussion' in one of the lateral edges, about two inches from the butt end. It was found alone, in the Breccia, in the eighth foot-level below the Granular Stalagmitic Floor, on June 2, 1880.

No. 7329. A flint chip, not quite an inch long, found alone, in the Breccia, in the ninth foot-level, on February 13, 1880.

No. 7330. Piece of bone, found alone, in the Breccia, in the seventh foot-level, on February 27, 1880.

No. 7331. A small polished agate, set in silver, found alone, on the surface, on March 5. This trinket of the present day must have been accidentally dropped by one of the numerous visitors to the Cavern since the four-feet excavation in that part of the Cavern was finished; that is, since February 1873.

No. 7332. A flint flake or chip, 3·1 inches long, 1·3 inch in greatest breadth, and nearly ·5 inch in greatest thickness. It retains a small portion of the original surface of the nodule from which it was dislodged, but has no indication of having been used or intended for use. It was found alone, in the Breccia, in the fifth foot-level, on March 6, 1880.

No. 7333. A flint flake or chip, 2·5 inches long, 2·2 inches in greatest breadth, and ·6 inch in greatest thickness. It retains a considerable portion of the original surface of the nodule from which it was struck, and was found alone, in the Breccia, in the eighth foot-level, on March 17, 1880. There is nothing about it to suggest that it was ever intended for use.

No. 7334. A left last upper molar of Bear, with a piece of bone, found alone, in the Breccia, in the seventh foot-level, on April 1, 1880.

No. 7335. A flint nodule, 3·6 inches long, 2·8 inches in greatest breadth, and 2 inches in greatest thickness. It is pretty much rounded, no attempt has been made to fashion it into a tool, and indications of its having been used as a 'hammer stone' are neither numerous nor well-pronounced. It was found alone, in the Breccia, in the sixth foot-level below the Granular Stalagmitic Floor, on April 13, 1880.

No. 7336. A small chert chip, found alone, in the Breccia, in the sixth foot-level below the Granular Stalagmitic Floor, on April 24, 1880.

No. 7337. A fragment of an unusually smoothly-worn pebble, or of the internal cast of an *Orthoceras*, found alone, in the Breccia, in the ninth foot-level below the Granular Stalagmitic Floor, on May 21, 1880.

No. 7338. A small flint chip, found alone, on May 31, 1880, in the Breccia, in the fifth foot-level below the Granular Stalagmitic Floor.

No. 7339. A flint nodule-tool, 5·75 inches long, 3 inches in greatest breadth, and 2·7 inches in greatest thickness. In form it approaches a four-sided pyramid; at the butt end each face is covered with the original crust of the nodule, and the apex is not well formed.

No. 7340. A mass of flint owing its present irregular form to artificial chipping, but not entitled to the name of tool. It is 3·35 inches long, 2·9 inches in greatest breadth, 1·8 inches in greatest thickness, and retains a small patch of the original surface of the nodule, where there are a few bruises such as might have been produced by its having been used as a 'hammer-stone.' It was found alone, in the Breccia, in the

ninth foot-level below the Granular Stalagmitic Floor, on June 15, 1880, that is the fourth day before the suspension of the work.

It may not be out of place to remark here that the second, that is the deeper, excavation has yielded a greater number of archæological than of palæontological 'finds'; and that whilst no animal relic was found below the seventh foot-level, the three fine nodule-tools (Nos. 7323, 7328, 7339) were found in the eighth foot-level, and several flint chips occurred in the ninth or lowest.

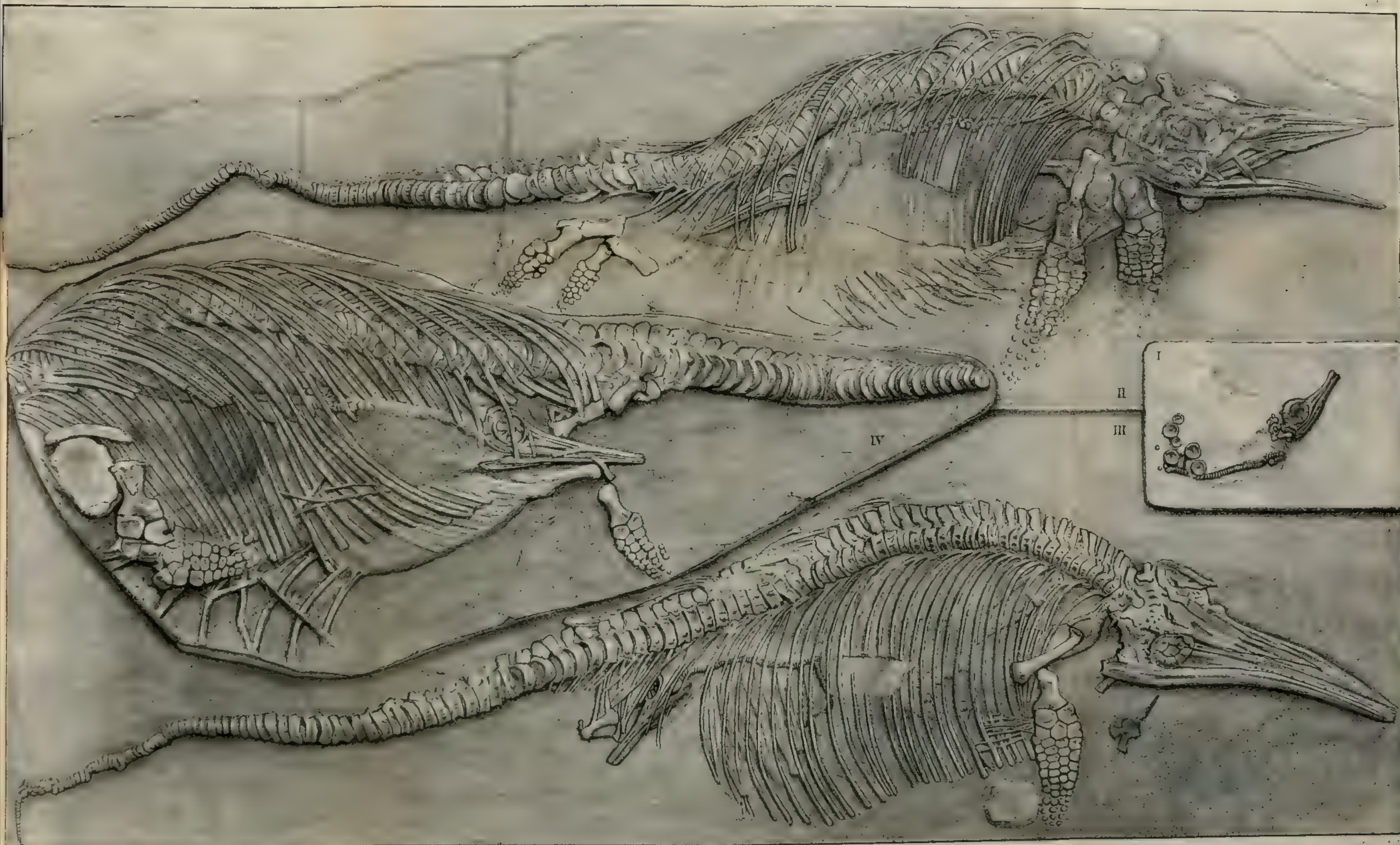
In closing their Report the Committee beg to express their thanks to Lord Haldon for so freely and kindly allowing them the entire control of the Cavern whilst carrying on the exploration; to the Committee of the Geological Section for their uniform, firm, and most encouraging support; to the General Committee of the Association for their liberal annual grants during a period of sixteen years, which have resulted in an instance of Cavern-exploration without parallel, it is believed, in this or any other country, for, at least, its continuity and duration; and to the private friends whose timely and kind donations enabled a considerable and satisfactory deeper excavation to be made, and thereby to give the work a nearer approach to completeness than would otherwise have been the case.

Finally, the Superintendents feel that it would be less than just were they to fail on this occasion to state, not merely the satisfaction, but the admiration with which they review the manner in which the work has been done by George Smerdon and his co-labourers in the Cavern. From the first day of the exploration—March 28, 1865—to its suspension on June 19, 1880, Smerdon was continuously engaged on the work, and for nearly thirteen years he was the foreman. During the entire period he not merely discharged his duties in a most faithful manner, but he never had a misunderstanding with the Superintendents.

Report on the mode of reproduction of certain species of Ichthyosaurus from the Lias of England and Würtemberg, by a Committee consisting of Professor H. G. SEELEY, *F.R.S.*, Professor W. BOYD DAWKINS, *F.R.S.*, *and* Mr. C. MOORE, *F.G.S.* *Drawn up by* Professor H. G. SEELEY.

[PLATE I.]

MINUTE Ichthyosaurian skeletons found in the Lias have, from time to time, raised a suspicion that the young of Ichthyosaurus might possibly pass in their development through a tadpole stage, since the smallest specimens show no indication of limbs. Prof. Haughton, in his 'Manual of Geology' (2nd edit. 1866, p. 272, fig. 37), has figured a small individual of this kind from the Lias of Boll. A less perfect specimen, 9 inches long, from the Lias of Charmouth, preserved in the Woodwardian Museum, is devoid of all traces of limbs. These small specimens, like the young of all vertebrate animals, are characterised by the relatively large size of the head. This uncertainty as to the mode of reproduction of Ichthyosaurus, has perhaps received some countenance from the circumstance that Prof. Owen, in his



Illustrating the Report on the Mode of Reproduction of certain Species of Ichthyosaurus from the Lias of England and Würtemburg

'Anatomy of the Vertebrates' so far hesitated about the true nature and classification of Ichthyosaurs as to speak of them in one place (vol. i. p. 50) as Dipnoa, although as a rule they are arranged with the Monopnoa. So far as I can learn, there is no evidence in support of Prof. Haughton's hypothesis that Ichthyosaurs pass through a metamorphosis. But, on the contrary, a number of examples, British and foreign, enforce a conviction that several species of the genus brought forth their young alive. In all cases they appear to have been retained in the body of the parent till a comparatively large size had been reached. Attention was first drawn to this characteristic of the genus by the late Dr. Chaning Pearce, of Bath, who, in 1846, contributed to the 17th volume of the 'Annals of Natural History,' a paper entitled 'Notice of what appears to be the Embryo of an Ichthyosaurus in the pelvic cavity of I. communis.' In his note it is stated that the large animal from the Lias of Somerset is about eight and a half feet long. The little animal lies at full length in the pelvis, with its head directed towards the tail of the large one, and is supported upon the internal surface of its integument and upon the internal surfaces of three posterior ribs of the left side. The young animal measured five and a half inches in length. The rami of the jaws and one of the longest ribs, of which only five or six are visible, are each an inch long; and of the thirty vertebræ which can be counted the largest measures an eighth of an inch in its longest diameter.

This minute specimen is bounded on each side by the ilium, ischium, and pubis, and by the right and left posterior paddles, and on the right side by the vertebral column and ribs which extend from it. The posterior two-thirds of the little animal is within the pelvis, but the head appears to protrude beyond it, and was apparently in the act of being expelled at the time of death. The late Dr. Chaning Pearce remarks on the correct position of this minute skeleton in the pelvis between the right and left ribs, with the head protruding; and from the exact correspondence between its bones and those of the large Saurian draws the inference that it can only be a fœtal Ichthyosaurus. During the meeting of the British Association in Bath in 1864, it was my good fortune to have an opportunity of studying this specimen, and it enforced in my mind the same inference that was enunciated by its discoverer. Its perfect condition of preservation, size, and position in the body seem to me completely to refute the current opinion of those days when Dr. Pearce's conclusions were not accepted, that the young animal might have been swallowed whole, and have gradually found its way to the position in which it was fossilized. This view Dr. Chaning Pearce combated by remarking that had so delicate a structure been swallowed whole it could not have reached its present place without being dissolved by the gastric juice.

Among the series of Ichthyosaurs presented to the Woodwardian Museum, by Thomas Hawkins, Esq., is a large slab with the remains imperfectly preserved, but containing a disturbed skeleton of a young Ichthyosaur in the pelvic region. The vertebral column has the vertebræ in sequence, and the head is remarkable for the high form common in embryos (fig. 1). Taken by itself no inference as to the mode of reproduction could fairly be drawn from this fossil, but as a link in a chain of evidence it has some value. A third British specimen is said to have occurred in the Lias of Lyme Regis, and to have shown a number of embryos in the pelvic cavity. I have not seen this specimen, but Mr. Henry Keeping, who first reported its existence to me, considered that it was altogether incon-

clusive upon the mode of reproduction of the Ichthyosaurus. Mr. Charles Moore has examined the specimen and is doubtful as to the inference that should be drawn from it. These are the only British specimens which bear upon the mode of reproduction in Ichthyosaurs.

I am aware that it may be fallacious to reason from the structures of living reptiles back to the nature of soft parts in an Ichthyosaurus; but in the alligator, which is also a carnivorous animal, the contents of the stomach remain there till perfectly dissolved, and in a specimen 11 feet long, the pyloric aperture was only about an inch in diameter, and defended with two valvular constrictions, so that, supposing the Ichthyosaurs to have preyed on their own species, and to have swallowed their prey head first, after the manner of snakes, there is an *à priori* improbability that the young animal would have got farther than the stomach, which in alligators is placed well forward, and is not unduly large. Moreover, I see no reason to doubt that the substances from the Lias of the South of England which are well known as Ichthyosaurian coprolites have been correctly determined. They consist of well-digested materials, and sometimes contain the scales of ganoid fishes, and hooks of cuttles, such as are met with in the stomachic region of many individual Ichthyosaurs. I have elsewhere taken occasion to point out that the spiral structure which these coprolites display indicates that there was, anterior to the rectum, a smaller intestine of the calibre of the coil which is wound into the coprolite;[1] and it is obviously impossible, even if the young specimen could have passed the stomach uninjured, for it to have passed uninjured down such a small tube, so that the snout should project from the body in the way which Dr. Chaning Pearce has described.

Unfortunately Dr. Chaning Pearce did not give a figure of his specimen, and so the discovery missed alike recognition and recollection. I lost sight of the specimen until last year, when I learned that it had been removed to Brixton, and with the rest of the collection it was shown to me by Dr. Joseph Chaning Pearce, F.G.S. But whether pyrites in it had decayed, or whether it had suffered in the lapse of years from cleaning and removal, the fact remains that the young specimen is gone. The question here ends in a *cul-de-sac*, so far as the English evidence is concerned.

An interesting Ichthyosaur in the Royal Museum at Stuttgart, to which my attention was drawn by Dr. Oscar Fraas, in August, 1878, would appear to have been the original of a figure by Dr. G. F. von Jaeger, published in 1824, in his work 'De Ichthyosauri sive Proteosauri, &c.,' which I have hitherto been unable to see.

It is certainly the original of a very rough figure, Tab. I. fig. 4, probably the same plate, given by Dr. von Jaeger in his work, 'Ueber fossile Reptilien welche in Würtemberg aufgefunden worden sind,' published at Stuttgart, in 1828. But although the young animal is figured as lying in the abdominal cavity of the large individual, the author does not even refer to its remarkable position, and confines his observations to an account of the structure of the genus, and an endeavour to determine the species. And it was not till Dr. Chaning Pearce's note became known in Germany that attention was awakened to the bearing of this and of some similar specimens.

Other writings of Dr. Jaeger contain evidences of his renewed interest in this subject, for in the 'Nova Acta Ces. Leop. Car.' vol. xxv. pt. 3. p. 961,

[1] *Index to fossil Remains of Aves, Ornithosauria, Reptilia, &c.*, p. 131, 8vo. 1869.

four Ichthyosaurs are referred to, which each contained a fœtus. One of these is the specimen originally figured by himself;[1] the second is at Tübingen; and the third from Zell, near Kirchheim, was exhibited at Munich in 1854. He remarks that these are all entirely enclosed between the ribs of the parent, are all fully developed, and were ready to be born, or in the act of being born, as the animals sank to the bottom. 'In these three cases the head, though still in the body of the old animal, is directed backward. On the other hand, one specimen of Ichthyosaurus from Ohmden, now at Madrid, has the head of the young one directed forward, and in sequence with a connected series of vertebræ.' Jaeger argues that the young do not exhibit any trace of having been eaten, since no digested matter is found with them, while the vertebræ are in sequence, and the bones hold the exact position they should have if the Ichthyosaurus were viviparous. And he further remarks, that though these young examples are rare, yet they really exist, while we find no traces of any eggs, though numerous coprolites are preserved; and from the circumstance that the skull in the young of these German specimens belongs to the same species as the old animals, concludes that, at least, the species which he names *Ichthyosaurus tenuirostris* was viviparous.

Other important and beautiful specimens have been acquired for the University Museum at Tübingen, by Professor F. A. von Quenstedt, F.M.G.S., and admirably developed by him. They are briefly noticed in his well-known works, 'Der Jura' and 'Epochen der Natur,' but they led the learned and accomplished author to the conclusion that the young specimens had been devoured. In the former work (1858, p. 219), after describing the species, which he names *I. quadriscissus*, it is observed, 'this specimen contains a young one between the ribs, in a position which indicates that it was eaten. The splendidly preserved skull of the young one measures 10 inches in length, with its point towards the hinder extremity, while its tail still remains in the throat. Hence we may infer that the intestinal canal was as simple as in sharks.' And in the later work, published in 1861, p. 549, these statements are repeated, except that two specimens are mentioned as being in the Tübingen collection. Though no argument is offered upon the subject, the large size of the young, and extent to which its tail reaches forward in one of his specimens, has evidently weighed with the Tübingen professor in the printed expression of his judgment. He, however, called my attention to a small specimen in the University Museum, with the tail coiled up, which he thought might have been fœtal, but it is not contained in the body of another animal.

In 1876, Arnold R. C. Wurstemberger printed in the 'Jahreshefte Ver. Nat. Würtemburg,' a memoir entitled 'Ueber Lias Epsilon,' which concludes with some account of the species of Ichthyosaurus, giving an interesting description of *I. quadriscissus* (*Q*). After describing a large parent animal, in which the head is said to be 50 c.m. long, and the vertebral column 240 c.m. in length, Wurstemberger observes that the stomach lies unusually far forward, being only 20 c.m. behind the head, and is defined by containing fish-bones and the dark-coloured remains of cuttle-fish. A small Ichthyosaur lies entirely behind this region, and is so contained between the ribs, that the author is convinced that it could not have got there after the death of the large animal, hence it can only have been eaten or be an embryo. Many bones of the young

[1] *De Ichthyosauri sive Proteosi fossilis specim. in agro Bollensis repertis.* 1824 fol. Tab. I. fig. 4A.

animal are scattered, and appear to have been washed out of the large animal, but are always on the ventral side. The entire animal is a good deal confused, so that the co-ordination and order of the parts can only be made out after careful study. The bones of the young animal, from being less mineralised than those of the large individual, are much softer. The largest vertebra is about 4 m.m. in diameter, so that, reckoning sixty vertebræ, the author estimates the length of the vertebral column of the small animal at 24 c.m. The head is not only entire, but shows the sutures between the bones. The sclerotic plates form the usual circles defending the eyes. The jaws show no traces of teeth, and from their excellent preservation Wurstemberger inferred that none existed. It is, however, he says, most remarkable that the snout is not turned towards the hinder part of the large animal but towards its head, and the vertebral columns are parallel to each other. This specimen I have not been able to examine, and no figure of it has been published; but although apparently less well preserved than some others, I believe it to be embryonic, and that the position of the young animal may possibly have been the cause of death in the parent. For, after the author's account of the unusually forward position and contents of the stomach, I do not accept his doubts as to whether the specimen really justifies the embryonic hypothesis, in face of the cumulative evidence that at least six specimens are known which each demonstrates the same fact of the presence of a young Ichthyosaur, in good preservation, in the posterior abdominal region of the large specimens.

Finally, just as I was leaving Tübingen, Herr Kocker, Professor Quenstedt's obliging and excellent assistant, mentioned to me that there is at present at Reutlingen for sale an Ichthyosaurus, which is alleged to contain several young specimens in various stages of development. Being unable to go to see this specimen, I obtained a photograph of it, but unfortunately the animal appears to have lain upon its back and side, in such a position that the ribs of the upper side of the body have fallen together, leaving the abdominal cavity exposed. Beyond all doubt, there are the remains of several small Ichthyosaurs in and about the hinder abdominal region, but their condition is not so clear as in other specimens, and the circumstance derives its chief weight from being a link in a chain of evidence, and its interest from repeating a condition shown by the Lyme Regis specimen referred to.

Of all this material no illustration has been given excepting the rough and almost worthless figure by Dr. von Jaeger, published between fifty and sixty years ago. I am, therefore, glad to be able, by the kind co-operation of Dr. Oscar Fraas, to submit a photograph (of which Plate I. is a copy) of this the earliest found example illustrating the relation of the young to the parent Ichthyosaur.

I am also greatly indebted to Prof. von Quenstedt for having allowed me to have photographs made of the two most striking specimens in the University Museum of Tübingen. Hence these three figures will enable those to whom the originals may be inaccessible to judge of the nature and value of the evidence to which I have already referred. It may, however, be useful if I append a few descriptive notes on the characters of the specimens. The determination of the species I purposely leave for a memoir, in which I trust to give a systematic revision and determination of the British and foreign Ichthyosaurs; and this subject is so beset with difficulties, that it may yet be some time before a species of Ichthyosaurus

can be defined with the same accuracy and certainty as characterises other kinds of palæontological work.

The specimen in the Royal Museum at Stuttgart (fig. 4) wants the head and the hinder half of the tail, in which the vertebræ become greatly attenuated. The portion of the animal preserved is about 5 feet long, and of this length rather less than two-thirds is comprised by the body region of the animal, in which dorsal ribs are developed. The fore limb lies somewhat bent on the ventral margins of the ribs, and the hind limb is well preserved below the pelvic region. From the apparently firm union of the ribs to the dorsal centrums they have been pulled somewhat apart, and do not approximate towards their ventral edges. This animal lies upon its left side, inclining a little towards the back. As usual there is an upward arch of the anterior half of the dorsal region. The young animal lies in the abdominal cavity, and, although not perhaps so fully developed as might be, its length, so far as can be made out, appears to be about 2 feet 6 inches. The vertebral column is parallel to the vertebral column of the large animal, and is separated from it by an interspace of $2\frac{1}{2}$ inches in the posterior region of the large animal, becoming anteriorly a little farther distant from it. The young animal lies upon its right side, and although the ribs have been strained from their natural position, the young animal is still entirely between the ribs, except where a few of them have been purposely removed, the better to show its characters. The head of the small animal is about 10 inches long, and rather more than $2\frac{1}{2}$ inches deep at the hinder border of the orbit. The snout projects from the abdominal cavity in the region of the pelvic bones for about a third of its length, but the pelvic bones are no longer *in situ*, owing to the conditions of fossilisation. The dorsal region of the young specimen has not been so developed as to show its ribs, but the vertebral column is in sequence, though the pressure of the overlying ribs of the large animal has somewhat broken the chain, and exposed the faces of one or two of the few vertebræ, the largest of which in the lower dorsal region has a diameter of half an inch. The depth of the body of the young animal was apparently $4\frac{1}{2}$ inches. The extremity of the tail is not seen. It may be noticed that the ribs of the large animal extend over the eye and nasal region of the left side of the young head, but the shortening of the ribs on the left side of the large animal shows that the snout could hardly have been contained entirely within the pelvic cavity if the young animal occupied its present position during life. It is of course possible that there may have been some slight shifting of position; but the presence of the abdominal ribs of the large animal *in situ*, and the generally undisturbed character of the remains, lead me to believe that the relative positions of the two individuals are not now greatly different from what they were during life.

I can only endorse the conclusions of Von Jaeger that we have here a fœtus in the act of being expelled, and although the size of the young animal is relatively large, it is not unparalleled among living amphibians; and the eggs of birds vary so much in bulk, that with gigantic eggs, such as those of Æpiornis, the large size of this embryo is not unexampled. The great extension of the young in the body of the parent need perhaps present no difficulty when we remember the large space occupied by the ovarian organs in the lower vertebrata; and, large as the young animal is, there is no known limit to the capacity for expansion of the oviduct which would render its size and position improbable on such an explanation. If it were asked why the old animal should have died, I can only state that

it has been my fortune to dissect a porpoise in which the fœtus was similarly placed, and the parent animal was driven ashore in an obviously enfeebled condition, consequent probably upon the function in which it was engaged, and if such a specimen had been fossilised it would have exactly paralleled these fossil Ichthyosaurs.

The specimens in the Tübingen Museum (figs. 3, 4,) are in some respects more instructive since the heads of the parent animals are preserved, the ribs are less disturbed, and the skeletons are altogether more complete. The specimen exhibited in the Museum, which is from Holzmaden in Würtemberg, is numbered 7532. The parent animal has the skull-bones somewhat displaced; they are about $14\frac{1}{2}$ inches long, while the length of the vertebral column is 8 feet $3\frac{1}{2}$ inches, the fore limb is 16 inches long, and the hind limb $8\frac{1}{2}$ inches in length. In the dorsal region there are forty vertebræ with double-headed ribs; then follow six with single-headed ribs, and in about this position the ilium was placed. The caudal vertebræ number 105. The length of the abdominal region of the large animal is 3 feet 6 inches. The iliac bones are relatively large, flattened, and oblong, and measure $3\frac{3}{4}$ inches in length. They have been a little displaced, so that the hinder limbs lie just below the vertebral column.

Entirely within the abdomen is a small Ichthyosaur, lying between the right and left ribs, with its head directed towards the posterior region of the body, the extremity of the snout being separated from the present position of the iliac bones by a width of about five vertebræ. The vertebral column of the small animal is parallel to that of the large one in which it is contained. The head, which is well preserved, is $10\frac{1}{2}$ inches long, has teeth in both jaws, has the eye-plates well developed, and the orbital cavity about 2 inches in length. The region of the fore limb is missing, owing apparently to a fracture of the fossil in extracting it in the quarry. The dorsal vertebræ and dorsal ribs are well shown. The centrums here have a diameter of $\frac{1}{2}$ inch. The vertebral column can be traced within the large animal for 21 inches, but the series is a little scattered, and towards the end the vertebræ are obscure from their small size. The interspace between the two vertebral columns is only about 2 inches; the depth of the body of the large animal was probably about 23 inches. It is to be remarked that there is no indication that I could detect of the tail of the small specimen reaching so far forward as to justify the expression that it was in the throat.

The second Tübingen specimen is contained in the work-room, and has no catalogue number.

It is of much larger size, has the dorsal vertebræ and ribs in natural position, but the hind limbs do not appear to be present, though the iliac bones remain, slightly displaced. The skull is here 24 inches long. There are 45 vertebræ, with double-headed ribs, measuring, as preserved, 4 feet. To them succeed two vertebræ, with large single tubercles, which are usually regarded as sacral; then 31 vertebræ, measuring 2 feet 8 inches, which form the large anterior part of the tail; and then succeed 47 vertebræ of much smaller size; but the extremity of the tail is not preserved. The abdominal ribs are not well seen, but the depth of the body is about 25 inches. The fore limb in this animal is $13\frac{3}{4}$ inches long. From these and other considerations, which it is not within my present province to dwell upon, it is evident that we have here a distinct species from the specimen just described. The young animal lies entirely between the ribs of the large one in the posterior part of the abdomen, with its back

towards that of the large individual in which it is contained, as is the case with the other specimens which I have described. The head is directed downwards, and the snout extends beyond the limits of the ribs, as though it were just protruding from the body. The extremity of the snout is imperfect, but the head, as preserved, is 9 inches long. The vertebral column has a total length seen of 20 inches, but may extend further under a rib. The vertebræ are in natural sequence, though the caudal region is bent round in a curve ventrally; but it is difficult to say whether this is the position natural to the embryo. The dorsal vertebræ are $\frac{1}{2}$-inch in diameter, and the corresponding centrums of the large animal are $2\frac{1}{4}$ inches in diameter. The ribs of the young animal are preserved, and there are bones which appear to be coracoids. The hind limb is distinctly preserved, and measures $1\frac{1}{8}$ inch in length. The femur is $\frac{3}{8}$-inch long, and the smaller limb-bones are in three rows. It is unfortunate that the hind limb of the parent is not available for comparison, but that portion of the original slab is missing. So far as it is possible to compare the pointed snout and teeth of the young with the large animal, there is nothing to suggest that they belong to different species.

After thus detailing the facts as to the position and character of these specimens, the conclusion to be drawn from them may be left to a consideration of the cumulative evidence of the figures; and if I do not formally discuss the view which Prof. Quenstedt has adopted, that these specimens were eaten, it is because no other animals except Ichthyosaurs have ever been found in the hinder part of the abdominal cavity of large specimens of this genus; and because the remains of fishes and cuttles, which appear to have constituted the ordinary food of these sea-monsters, are always found, comminuted and indistinguishable in form, in a more anterior position. It is improbable that the large animal, with its comparatively firm quadrate bones, would have been capable of swallowing a creature in which the head, as in the first Tübingen specimen, was more than two-thirds the length of its own head, without in any way crushing or breaking the structure, or even disarranging an eye-plate; while the evidence from the structure of coprolites seems to me to render superfluous any further discussion of this question of the young animals being in process of digestion. That the small specimens were washed in a dead state into the already dead bodies of the large specimens is a hypothesis that can need no discussion; for the many cases in which the two bodies are parallel, with the smaller placed entirely within the larger, have no appearance of accident, while a movement of the sea which would wash the young about in such a way would probably scatter the bones of both animals.

I therefore submit that the evidence indicates that these Ichthyosaurs were viviparous, and were probably produced of different relative bulk in different species; and it may be from feeble health of the parent or from some accident of position in the young that they were not produced alive, and thus have left a record of their method of reproduction to which no allied extinct group of animals has shown a parallel. There is some evidence that in certain cases many young were produced at a birth, and although the specimens are not in the best state of preservation, analogy strongly suggests that this is a distinctive character of certain species. It cannot be taken as proved that all Ichthyosaurs were viviparous; for the character, though met with among fishes, amphibians, and reptiles, is not distinctive of any living order of these animals; and it

is therefore probable that many species in this extinct ordinal group produced their young from eggs, like the majority of their living allies.

I would express my thanks to the Council of the Royal Society for assistance in examining the museums of Europe in which remains of Ichthyosaurs are contained; as well as to Dr. Fraas, Prof. Quenstedt, and Prof. McK. Hughes, for the facilities so freely afforded me for studying the specimens in the collections over which they preside.

EXPLANATION OF PLATE I.

Fig. 1. Small portion of Woodwardian specimen showing part of young Ichthyosaur, with a few caudal vertebræ of the large animal.
Figs. 2 and 3. The two Ichthyosaurs with young at Tübingen.
Fig. 4. The imperfect Ichthyosaur with young at Stuttgart.

Report of the Committee, consisting of Professor P. M. DUNCAN *and* Mr. G. R. VINE, *appointed for the purpose of reporting on the Carboniferous Polyzoa. Drawn up by* Mr. VINE (*Secretary*).

As so much remains to be done before the Palæozoic Polyzoa can be properly classified—more particularly the Carboniferous species—it seems to me that the wisest course to adopt in this Report, is to go carefully over the work of other authors, reviewing their labours generally, and giving, in as condensed a form as possible, the results of their varied efforts.

David Ure,[1] the son of a working weaver in Glasgow, is the first, so far as I am aware, who drew attention by figures to British Carboniferous Polyzoa; and Martin[2] gives some good figures of Zoophyta, but species of these belong to both the Corals and Polyzoa. Thirty-five years after the publication of Ure's work, Dr. Fleming[3] named some of the species figured, and the Zoophyta he called *Cellepora Urii* and *Retepora elongata*. The first of these, according to Mr. Robert Etheridge, Jun.,[4] is *Chætetes tumidus*, Phillips, and the other is a *Fenestella*.

In 1826, the work of August Goldfuss[5] was published. In this a system of nomenclature was adopted, and many figures of Polyzoa and Corals given, which to a large extent assisted investigators and helped them to identify species found in this country. The generic terms used by Goldfuss were accepted by authors who followed him, but as no distinction was made by the earlier investigator in separating true Polyzoa from true Corals, those who worked from his types and descriptions fell into his error, and mingled, for a time, Corals and Polyzoa together whenever they had fresh forms to describe.

The chief of the generic terms used by Goldfuss were:—

1. *Gorgonia*, Linnæus, 1745.
2. *Cellepora*, Gmelin, 1788?
3. *Retepora*, Lamarck, 1816.
4. *Ceriopora*, Goldfuss, 1826.

The type of Linnæus' *Gorgonia* was altogether different from the types of Goldfuss's genus. The first had reference to the fixed Polypiferous

[1] *History of Rutherglen and East Kilbride*, 1793.
[2] *Petrifactions of Derbyshire*, 1809, *Petrefacta Derbiensia.*
[3] *History of British Animals*, 1828.
[4] *Ann. Mag. Nat. Hist.* 1874.
[5] *Petrefacta Germaniæ.*

mass which are still known by the same name, but the last are now referred to the *Fenestellidæ*.

The species of *Cellepora* are now placed with *Chætetes*, and most, if not all, of the *Ceriopora* of the Palæozoic era are also referred to *Chætetes* and to *Alveolites*.

The use of the term *Retepora*, as applied to Palæozoic fauna, has been abandoned, and the better defined generic term *Fenestella* used instead; but Lonsdale,[1] in his otherwise clearly defined characters of this genus, included both *Fenestella* and *Polypora* types in the one description of the genus.

However we may differ, at the present time, from Mr. John Phillips[2] in his arrangement of the 'Zoophyta' found in the Carboniferous rocks of Yorkshire, we must give him the credit for being amongst the first to attempt a division between Corals and Polyzoa; but in the use of Lamarck's genus *Millepora* for some of his species, he seems to have been very undecided as to the true character of his fossils.

Phillips describes eight species of *Retepora* defining certain terms which he uses, such as fenestrules, dissepiments, and interstices—terms still used in later descriptions of *Fenestella*. His species were *R. membranacea*, *flabellata*, *tenuifila*, *undulata*, *irregularis*, *polyporata*, *nodulosa*, and *laxa*. The poverty of Phillips' diagnosis renders identification of his species a very difficult matter, but some of his species were so truly typical in their general, as well as in their minute characters, as to enable Mr. G. W. Shrubsole, in his elaborate review of the *Fenestellidæ*,[3] to retain three of them as types of his very restricted Carboniferous forms. The retained species are:—

Fenestella membranacea, Syno. { *F. tenuifila*, Phill. and *F. flabellata* „ }
„ *nodulosa*, Phill.
„ *polyporata* „

The *Retepora flustriformis*, Phill. has been placed as a synonym of *F. plebeia*, M'Coy, by Mr. Shrubsole,[4] and as *Ptylopora* by Morris.[5] By Phillips it was regarded as the *Millepora flustriformis*[6] of Martyn, and he also said it resembled the *Gorgonia antiqua* of Goldfuss. *Retepora pluma*, Phill., is now *Glauconome*; and *Flustra? parallela*, which Phillips describes as 'Linear: longitudinally and deeply furrowed, cells in the furrows, in quincunx, their apertures oval, prominent'[7]—M'Coy[8] refers to the genus *Vincularia*, Defranc, and Morris[9] places it and another species of M'Coy's with the genus *Sulcoretepora*, D'Orb. This species has no affinities with any of these genera; it appears to me to be the Carboniferous descendant of the more ancient *Ptilodicta*, Lonsd. (= *Stictopora*, Hall). The non-celluliferous, striated, sometimes rugose margin, and the central laminar axis, or septum, which divides the cells of opposite sides, are almost always present in the Carboniferous species. I shall, therefore, prefer to leave the *Flustra?* which Phill. describes with the *Ptilodicta* as *P. parallela*, Phill., and this reference is founded upon original investigation of various specimens of *Ptilodicta*, of the American Silurian species,[10]

[1] *Geology of Russia.*
[2] *Geology of Yorkshire*, 1836.
[3] *Quarterly Jour. of Geo. Soc.* for May, 1879.
[4] Ibid. p. 278.
[5] *Catalogue of British Fossils.*
[6] *Petrefac. Derbiensia.*
[7] *Geo. of Yorkshire.*
[8] *Syn. Carb. Fos. of Ireland.*
[9] *Catalogue of British Fossils.*
[10] *Niagara Group: Palæontol. of New York*, Hall, vol. ii.; *Nat. Hist. New York*, part 4.

Ptilodicta Meeki, Nicholson, Devonian species,[1] as well as all the known species of *Sulcoretepora* of the Carb. Limest. series.

The *Millepora* of Lamarck seems to have been the generic type of both Goldfuss and Phillips, and in describing the Carboniferous species, the latter author adopted the class Polyparia of the Radiate Division of the Animal kingdom at that time current among naturalists. It was Phillips' misfortune, rather than his fault, that he had to follow in his classification the authority of those who preceded him. Of the six species of *Millepora* described, four are easily identified; the other two are not so easily recognised.

Millepora rhombifera, Phill., Geo of Yorkshire.
,, interporosa ,, ,, ,,
,, spicularis ,, ,, ,,
,, oculata ,, ,, ,,
,, gracilis ,, Palæozoic Fos. of Devon, &c.
,, similis ,, ,, ,, ,, Torquay.
,, verrucosa, Goldfuss. Of this Phillips say, 'a species like this appears at Florence Court, Ireland.'[2]

No group of Polyzoa, recent or fossil,[3] has caused so much trouble to Palæontologists as the little group here tabulated from Phillips. Members of it have been referred to no fewer than five distinct genera, and even now they may be safely referred to three, if not to four. Rather than postpone the analysis of the species, I shall prefer to draw upon later work and do it here instead of elsewhere.

Millepora gracilis is referred to by Phillips in his later work,[4] for he seems not to have noticed it in the limestone, Yoredale limest., or shales of Yorkshire; yet it is most common from everywhere, whilst the *M. rhombifera* is by far the rarer species. We have the authority of Phillips himself, that the species I am dealing with, were his; for in a letter[5] which he addressed to the Messrs. Young of Glasgow, he says, 'I agree with you in referring your beautiful specimens to the three species (*M. gracilis*, *M. rhombifera*, and *M. interporosa*) named in my books ("Yorkshire," vol. ii. and "Palæozoic Fos."). Your examples are better than mine were; but I have no doubt of the reference, &c.' Morris places the whole of Phillips' species—with the exception of *M. spicularis* and *M. oculata*—with the *Ceriopora*,[6] the exceptions, for what reason I cannot explain, he places with the *Pustulopera* of Blainville, a genus that had no existence in the Palæozoic seas.

Millepora rhombifera, Phill., Geo. Yorkshire.
,, *gracilis* ,, Palæozoic Fos.

Both Ceriopera, Morris Catalogue.
Rhabdomeson gracile and *R. rhombiferum*, Young & Young.

Gen. Ch. *R. gracile*.—'Stem slender, cylindrical, branching at right angles to the stem and never less than an inch apart; and consists of a hollow axis formed by a thin calcareous tube, and of a series of cells ranged round the axis . . . apertures of cells, oval . . . ridges tuberculated.'[7]

R. rhombiferum.—'Stems slender, cylindrical, free; branches of nearly

[1] *Geo. Mag.*, 1875, pp. 19–20, pl. 6, fig. 14. [2] *Geo. of Yorkshire.*
[3] Excepting the *Lepralia*.
[4] *Palæozoic Fos. of Cornwall, Devon &c.*, 1841.
[5] April 3, 1874; *Ann. Mag. of Nat. Hist.*, May, 1875.
[6] *Catalogue of British Fossils*, 1854.
[7] Messrs. Young, *Ann. Mag. of Nat. Hist.*, May, 1874.

equal diameter given off at wide intervals . . . cells in quincunx all round the stem; surrounded by tuberculated ridges . . . cell-area more numerous on one face than on the other . . . central axis slender, slightly flexuous, and without transverse septa.'[1]

For these two species, the Messrs. Young of Glasgow have founded a new genus—*Rhabdomeson*—on account of the peculiar central hollow axis which they possess, and on which the cells are arranged. This peculiarity is unique—for I know of no other Polyzoa having a rod or mesial axis similar to these. Some of the *Graptoloidea*, sub-order, *Rhabdophora*, Allman, possess a mesial axis, and so do the *Rhabdopleura*—class Polyzoa, order *Phylactolemata*—but whether we should be justified in assuming on this account, either Hydroid or Phylactolematous affinities for these fossils is a very serious question to decide. The assumption in either case would involve the discussion of many problems into which I cannot enter here. The Messrs. Young, in the two papers referred to, have gone into the question very fairly, and those who follow them in their critical remarks must remember that they are contending for the antiquity of a type of Polyzoa organisation not—previous to their discoveries—known to exist in a fossil state. I have carefully followed the authors in all their investigations of this intricate question, but I am not prepared to use this fossil type as in any way indicative of the existence of *Phylactolematous* Polyzoa in Carboniferous times. At the same time it would be mere carping on my part to ignore its existence as indicative of peculiar structural characters that may help us in our future classification of the Palæozoic Polyzoa.

Millepora interporosa, Phill. Geol. of Yorksh.
Ceriopora interporosa, Morris' Catalogue of Brit. Fos.
Vincularia Binniei, Etheridge, Jun.[2]

This species is a very variable one. Phillips speaks of it as having 'oval pores,' whilst the *Millepora similis* has more elongated pores; on the other hand *Vincularia Binniei* is spoken of as having 'oval to hexagonal cells arranged in quincunx; or in oblique ascending lines.' The magnified figure of a series of cells given by Mr. Etheridge as an illustration of his species, is one of the rarer varieties of *M. interporosa*. Had Mr. Etheridge contended for the variety, I should not have disputed his claim, but as he introduces a most anomalous genus into the classification of our Carboniferous Polyzoa, I cannot do otherwise than point out the anomaly. Defranc's genus *Vincularia* had no existence whatever in Palæozoic times. D'Eichwald, on whose authority Mr. Etheridge rests, is most unreliable on this point.[3] Junr

It is on account of their importance that I have dwelt so fully upon these species. They had a wide geographical range in Carboniferous times, and though their variability is great, they have many structural characters in common with the *Ceriopera* which range into the Mesozoic and Tertiary strata.

Under the auspices of Sir Richard Griffiths, of the Irish Geological Survey, Frederick M'Coy published his 'Synopsis.'[4] There is ample evidence in this work that M'Coy had much better material than Phillips, and

[1] Messrs. Young, *Ann. Mag. of Nat. Hist.*, 1875.
[2] *Geological Mag.*, April, 1876.
[3] *See* paper on *Vincularidæ*, mihi. Read before the Geo. Soc., June 23, 1880.
[4] Synopsis of the *Carb. Fos. of Ireland*, 1844.

his drawings and diagnosis of species are more elaborate. M'Coy adds no fewer than twelve species of *Fenestella* to our British Polyzoa. They are *F. plebeia*, *carinata*, *formosa*, *crassa*, *multiporata*, *ejuncida*, *frutex*, *hemisphe-rica*, *Morrisii*, *oculata*, *quadridecimalis*, and *varicosa*. As I shall have to speak of these farther on, I will leave the list without any further comment.

M'Coy retains a few puzzling forms under the name of *Gorgonia*. These are *G. assimilis*, Lonsd.; *G. Lonsdaleina*, M'Coy; and *G. zic-zic*, M'Coy.

Another fenestrate genus, introduced by M'Coy, bears the name of *Ptylopora*. There is a feather-like arrangement in this genus: a central stem giving off lateral branches which are connected by dissepiments having oval fenestrules. *Fenestella* owes its expansion to the bifurcation of its branches. *Ptylopora* very rarely bifurcates, there is a basal extension of the Polyzoary along the central stem. One species is recorded by M'Coy—*P. pluma*—but it is a genus that deserves to be more closely studied than it has been. In naming some fossils lately for Mr. John Aitken, F.G.S., from the neighbourhood of Castleton, Derbyshire, I detected several small fragments of this beautiful genus. The broad central stem, whenever fenestration was absent, might easily be mistaken for a robust Glauconome.

The Glauconomes, which M'Coy figures and gives a description of, are *G. grandis*, *G. gracilis*, and by his discoveries he extends the range of Phillips' *G. bipinnata*.[1]

The *Vincularia* I have already repudiated, and the *V. parallela*, Phill., which M'Coy accepts as a type, I have alluded to when describing Phillips' species. The *Berenicea megastoma*, M'Coy = *Diastopora*, Mor. Cat., will be placed in the genus *Ceramopora* on account of its many well-marked characters.[2]

Having all the material at hand for the work, I shall now discuss the relative value of the genera and species introduced by various authors since the publication of the volumes alluded to.

Synocladia, King, 1849.

1873. *Synocladia biserialis*, Swal., var. *Carbonaria*, Etheridge.
1877. *Synocladia ? scotica*, Young and Young.[3]

The type of this genus is very peculiar, and as it is well illustrated in King's Permian Fossils, once seen it can hardly ever be forgotten. 'The corallum is cup-shaped, with a small central root-like base: reticulated, composed of rounded narrow, often branched interstices, bearing on the inner face from *three to five alternating* longitudinal rows of prominent edged *pores*, separated by narrow keels, studded with *small irregular vesicles* alternating with the cell pores.' The essential characters of this genus I have underlined.

In the 'Ann. and Mag. of Nat. Hist.,'[4] Mr. Robert Etheridge, Jun., described a 'peculiar polyzoon from the Lower Limestone Series of Gilmerton, under the name of *Synocladia carbonaria*.' An almost identical form had been previously referred, by Mr. Meek,[5] to *Synocladia biserialis*, Swallow.[6] After very minute investigations, kindly supplied to him by

[1] Up. Devonian, Croyde, Pilton Devon, Phill., Palæozoic Fos.
[2] *See* paper on *Diastoporidæ*, mihi; paper read before *Geo. Soc.*, May, 1880.
[3] Dates of publication and reading of paper. The (?) is Messrs. Young's.
[4] Sept. 1873.
[5] *Palæontology of E. Nebraska*, Washington, 1872.
[6] *Transactions of St. Louis Acad.*, 1858, vol. i.

Mr. King,—Mr. Etheridge says, 'I have ascertained that our Scotch fossil agrees so closely in its main characters' with the American species, 'that it can be only regarded as a variety of it.'[1]

To *Synocladia biserialis* Mr. Meek also refers *Septopora cestriensis*, Prout, 'a form which appears to differ only from the typical species of *Synocladia* by having from one to four rows of cell-apertures on the dissepiment instead of two.'[2]

In 1878, Prof. Young and Mr. John Young published[3] details of another *Synocladia*, which they called *Synocladia* (?) *scotica* from the Upper Limestone Shales, Gillfoot and Garple Burn stating that 'in both localities it is very rare.' If we accept the departure from the original type of *Synocladia*, which I have no objection to, seeing that Prof. King uses the term for Palæozoic Polyzoa alone, then these two species of the genus may be recorded as existing in Carboniferous times. They have the 'small irregular vesicles alternating with the pores,' not unique with this genus, for several others contain a 'secondary pore.' Having examined this secondary pore in thin sections of Carb. species, I can only account for its presence as being indicative of the existence of a vibracula in these ancient types. There are, however, most essentially definite characters in the Carb. *Synocladia* yet to be accounted for. Very frequently, in even the smallest fragments, pores, similar to the secondary pores on the face, are constantly found on the reverse also. I know of no analogy in more recent fossil or living species to which I can refer to account for this feature in this ancient type.

1873. *Carinella cellulifera*, R. Etheridge, Jun.
1876. *Goniocladia cellulifera*, R. Etheridge, Jun.

This is a good typical genus and species, both well described.

Generic and specific ch.—Polyzoarium composed of angular, irregularly disposed anastamozing branches, strongly carinate on both aspects, but celluliferous only on one. No regular dissepiments; the branches bifurcate and reunite with one another to form hexagonal, pentagonal, or polygonal fenestrules of most irregular form. On each side the keel of the poriferous aspect are three alternating lines of cell-apertures.[4] The genus and sp., for there is only one, is well illustrated in the 'Geo. Mag.,' 1873.

1849. *Thamniscus*, King Permian Fos.

1873. Mr. Rob. Etheridge indicates the possible existence of a species of this genus in our Scotch Carbonif. rocks. 'The portions obtained are fragments of a robust, branching coralline, with a nearly circular section. . . . The cells are very pustulose or wartlike, with prominent raised margins. . . . The disposition of the cells and mode of branching is exceedingly like that seen in *Thamniscus dubius*, Schl. . . . As the margins (of the cells) in the present form are decidedly raised and prominent, might it not probably be a species of *Thamniscus?* If it be a new species of *Polypora*, I would propose for it the specific designation of *P. pustulata*.'[5]

[1] Sheet 23, *Scotch Geo. Survey*.
[2] Ibid. Expl. of Sheet 23.
[3] *Proceed. Nat. Hist. Soc.* of Glasgow, April, 1878.
[4] *Geo. Mag.*, 1873 and 1876. Expl. of Sheet 23, *Scotch Survey*, p. 101.
[5] Expl. of Sheet 23, Appendix, p. 102.

1875. The Messrs. Young of Glasgow, after recording the opinions of Mr. Etheridge,[1] describe *Thamniscus ? Rankini*, Young and Young, inserting between the generic and specific names a (?) 'Stems free, dichotomous, circular, about $\frac{1}{18}$ in. in diameter, branches in one plane. . . Cells arranged in spirals. . . Cell-apertures circular when entire, oval when worn; lower lip prominent. . . Non-celluliferous aspect finely granulated, faintly striate.' . . 'The generic position of the fossil is uncertain. . . Meanwhile, though strongly disposed to regard this fossil as a true *Hornera*, or a member of a closely allied genus, we think it safer to leave it in the Palæozoic genus.' In this the Messrs. Young are wise, but younger and less cautious observers, on the strength of the many peculiar affinities which this species has to *Hornera*, would have eagerly embraced this opportunity. I cannot, however, regard this species as a Palæozoic *Hornera*, but I must candidly confess that it comes very near to the generic description accepted by Busk.[2]

Glauconome, Munster, Sy. *Vincularia*, Def. 1829. *Glauconome*, Goldfuss, 1826. Revised by Lonsdale, 1839. (*G. disticha* Lonsdale, type of D'Orb.'s *Penniretepora*) ; *Acanthocladia*, King, 1849.

It is very doubtful whether this term can be used for other than Palæozoic Polyzoa. It was originally used by Munster for Cylindrical forms, for the *Glauconome marginata*, Munst., in Goldfuss' Petrefac. of Germany, is given by Hincks as a synonym of *Cellaria fistulosa*, Linn. It was, however, established by *Goldfuss*, and afterwards revised by Lonsdale. M'Coy,[3] improving upon Phillips'[4] poor description does not make any reference to the number of pores between the branchlets. In his later work he defines the Genus more minutely thus :—

'Corallum of a narrow central stem, with numerous pinnules, or lateral branches *unconnected* with each other : both stems and branches have two rows of cells on one face, which is usually carinated between them, carina in some species tuberculated ; opposite face striated.'[5]

In a paper read at the Nat. Hist. Soc., Glasgow, the Messrs. Young describe several new species of *Glauconome*.

1875.	*Glauconome*	*marginalis*,	Young and	Young.
	,,	*stellipora*	,,	,,
	,,	*elegans*	,,	,,
	,,	*aspera*	,,	,,
	,,	*flexicarinata*	,,	,,
	,,	*retroflexa*	,,	,,
	,,	*laxa*	,,	,,
1877.[6]	,,	*robusta*	,,	,,
1877.	,,	*elegantula*,	R. Etheridge,	Jun.

In describing *G. elegantula* Mr. Etheridge defines and criticises the genus *Glauconome* with especial reference to the *Acanthocladia*.[7]

[1] *Ann. and Mag. Nat. Hist.*, May, 1875, p. 335, pl. ix. *bis*.
[2] *Mar. Polyzoa*, pt. iii. Cyclostomata, p. 16.
[3] *Syn. Carb. Fos. Ireland.*
[4] Retepora pluma, *Geol. of Yorksh.*
[5] *Brit. Palæozoic Fos.*
[6] *Proc. Nat. Hist. Soc. of. Glas.* 1878. Paper read 1877.
[7] 'Notes on Carb. Polyzoa,' *Annals and Mag. N. H.* vol. 20, 1877.

1875. *Hyphasmopora*, R. Etheridge, Jun.[1]

The generic and specific characters of this new provisional genus are well described by Mr. Etheridge in the paper referred to. There is only one species—*H. Buskii*, and I am glad that after submitting the specimens to Mr. Busk, Mr. Etheridge followed his own judgment and established a new genus, rather than acting upon the indiscreet reference of Mr. Busk, who says, 'that the above resembled the genus *Vincularia*, Defranc'—adding afterwards, 'it is probably the type of a new genus, perhaps allied to the latter.' This beautiful species is found in several localities of Scotland, but I have found it in Yorkshire, and also in N. Wales. It cannot, however, be considered a common form anywhere.

1850. Sulcoretepora, D'Orbigny.

This genus has been accepted by Morris (Catal.) and by the Messrs. Young of Glasgow, for certain species of Carb. Polyzoa. Morris gives the above date, but the Messrs. Young in their paper[2] say 'The genus *Sulcoretepora* was formed by D'Orbigny in 1847, with the following definition:—Cells in furrows on one side of simple depressed branches.'

All the Carboniferous species that have been referred to this genus have cells on both sides, and, as I have already referred one of the accepted species to another genus, I will deal now with the *Sulcoretepora Robertsoni*, Y. and Y. As there are characters in this species altogether different from any known species of *Ptilodicta* the same reference for this as appears feasible for *Flustra? parallela*, Phill. is altogether out of the question. The *S. Robertsoni* has none of the characters in common with Phill. sp., and I should strongly recommend the Messrs. Young to construct for this typical species a new genus, especially so as 'Between each pair of cells in a longitudinal series, 1 to 3 pores occur, normally above each cell-aperture, and in well-preserved specimens tubercles surround each cell-area more or less completely.'[3] The *facies* of the species of Phill. and the sp. of the Messrs. Young may at first sight appear identical, but the forms described by the later authors are destitute of the non-poriferous, rugose, and striated margins of *Flustra? parallela*. It is upon the presence of this particularly constant character that I refer Phillips' species to *Ptilodicta*.

Archæopora nexilis, De Koninck.

This genus and species, classified as it is with the Polyzoa is a most peculiar one. I have not by me De Koninck's work for reference, and the remarks that I may offer upon the species—for I shall accept the genus without discussion—are the results of original investigation. The species is tolerably common in a few localities of Scotland. I have no record of it in this country except in doubtful fragments in Wales—and my type specimen was presented to me by Mr. John Young, and I believe I may safely conclude that this, with other specimens, was seen and approved of by De Koninck when he visited the Hunterian Museum of Glasgow.

Sp. Char.—Polyzoary adherent to stems of encrinites, shells, fragments of *Rhabdomeson*, *Ceriopora interporosa*, spines of Mollusca, &c.,

[1] *Provisional Genus of Polyzoa*, ibid. vol. xv. 1875.
[2] *Proceedings* of *Nat. Hist. Soc. Glas.* 1877.
[3] Ibid. p. 167.

spreading irregularly, forming large patches, at other times mere minute specs; pores generally oval, separated from each other by smaller openings. I cannot call them 'interstitial or cœnenchymal tubuli'—for that would convey a false impression, for pores and cells are netted together. The number of small openings surrounding a cell varies; sometimes there are as many as fifteen, in other places not more than five or seven. About twelve cells with their interjacent pores occupy the space of a line and half across the cells, from nine to ten in the same space in their length. The polyzoary is separated from the foreign objects to which it is attached by a very thin lamina formed by the bases of the cells. There is no evi-

FIG. 1.

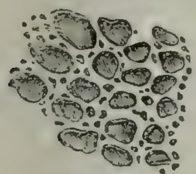


FIG. 2.

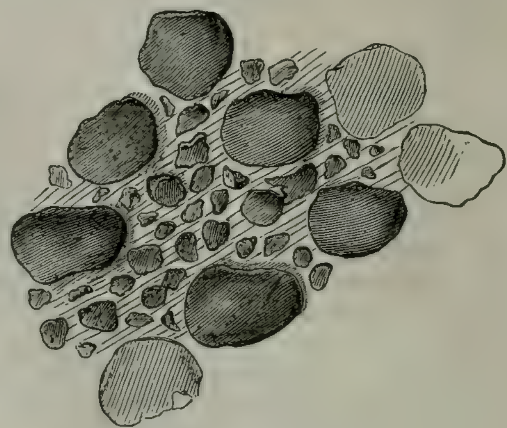
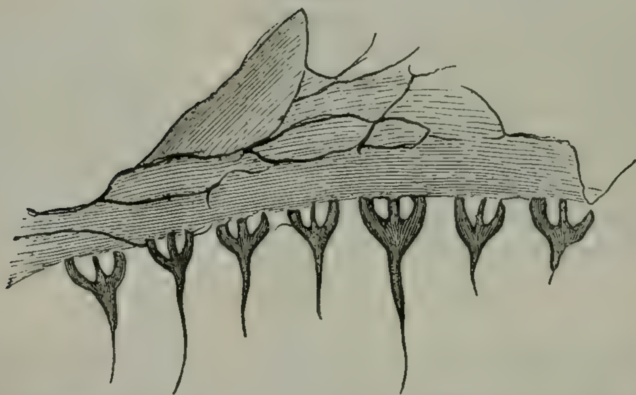


FIG. 3.



Archæopora nexilis, De Koninck, Capelrig E. Kilbride, Scotland.

FIG. 1. Showing the different sizes of the cells and interjacent pores.
2. More highly magnified, show vacant 'areolæ.'
3. Transparent, showing sections of interjacent pores; the long arm-like processes put in by reflected light.

(Drawn with *Camera lucida* by G. R. Vine, junr., *June* 1880.)

dence of tabulæ in thin sections, but the interjacent pores do not reach quite to the bases of the cells. I have never seen a specimen, on which a fresh colony is found spreading over an older one, but sometimes a colony of *Stenopora* is found upon the polyzoary of *Archæopora*. In a thin transparent section of a small fragment of another specimen, adherent to a portion of shell, a most peculiar structure is revealed—a drawing of which is given, which for a long time puzzled me—because the

peculiar biserial cells appeared like an analogous structure referred to by Prof. Nicholson when describing *Carinopora Hindei*, Nich.[1] His figures, however, are said to be transverse; mine are longitudinal, or in a line with the bases of the cells. These tail-like processes are constant characters at certain intervals in my very small section, and the figures given may help in the recognition of the genus in sections of limestone. At first sight *Archæopora* has the appearance of *Callopora incrassata*, as described and figured by Nicholson,[2] but a very little examination will show the difference between the two forms, whereas one is a Polyzoa and the other a Tabulate coral.

I have now gone over the whole of the recorded genera and species of British Carboniferous Polyzoa, with the exception of the *Fenestellidæ*. These having been so lately and so ably reviewed by Mr. G. W. Shrubsole, F.G.S., their omission from this report will not be so much felt as the omission of any of the other lesser known forms. Mr. Shrubsole, after very elaborate investigations, and after the careful comparison of nearly all the known so-called species, is inclined to restrict the twenty-six species to five typical ones, namely[3] :—

Fenestella plebeia—M'Coy
" crassa "
" polyporata—Phillips
" nodulosa "
" membranacea

all the other 'species' falling into the rank of synonyms of one or other of the five here received by him. But this does *not* confine the number of known species to five. When his labours on the family are completed several new forms will be described, together with at least two more species of *Polypora*—the results of laborious investigations in North Wales. There are also some references to the Polyzoa of the Carboniferous Limestone of the districts between Llanymynech and Minera, N. W., in the lately published work[4] of G. H. Morton, F.G.S., Hon. Sec. of the Liverpool Geological Society.

Several other papers on special points, having reference to Polyzoa, have been published during the last ten or twelve years. The vexed question as to the Hydrozoal or Polyzoal affinities of *Palæocoryne* has been debated by Prof. Duncan,[5] Prof. Young, and Mr. John Young,[6] and by myself;[7] but the question as to their real affinities is still an open one. Another paper by Mr. A. W. Waters,[8] entitled 'Remarks on some *Fenestellidæ*,' contains some debatable matter, and the papers of Mr. Robert Etheridge, Jun., on the genus *Glauconome*, Messrs. Young on the genus *Ceriopora*, and the paper on the 'Perfect Condition of the Cell-pores and other points of structure,'[9] are valuable additions to our knowledge of Carboniferous Polyzoa. Before any attempt can be made to construct a system of classification which will embrace—naturally—the several genera of the Palæozoic Polyzoa, many, at present, very doubtful points

[1] *Annals and Mag. Nat. Hist.* Feb. 1874, p. 81, figs. f and i.
[2] New Devonian Fos., *Geo. Mag.*, vol. i. 1874, page 2, plate 1.
[3] 'Carboniferous Fenestellidæ,' *Quar. Jour. Geo. Soc.*, May 1879.
[4] *The Carb. Limestone and Cefn-y-fedw Sandstone.* London, David Bogue, 1880.
[5] *Phil. Transac.*, 1869. *Jour. of Geo. Soc.*, 1873. *Jour. of Geo. Soc.*, Dec. 1874.
[6] *Jour. of Geo. Soc.*, Dec. 1874.
[7] *Science Gossip*, 1879.
[8] *Proc. of Manchester Geo. Soc.*, 1879.
[9] Newspaper Report, Oct. 9, 1879.

must be cleared up by a more complete study of all the species of the Palæozoic and Mesozoic ages of our earth's history. It is a difficult matter with present classifications to place the Genera of Palæozoic Polyzoa without doing violence to constructed definitions. In the absence, therefore, of any well-defined families in which the Carboniferous Polyzoa can be placed, I venture to group the whole of the forms under separate headings, which must be considered as provisional only. But to prevent any misconception as to the special characters of each group, I shall refer to the shape of the cell or zooecia especially, as the basis of my arrangement, allowing all the other characters to fall into their places as subordinate only.

Fam. I.—FENESTELLIDÆ.

Primary Char.—Polyzoary forming small or large fenestrated or non-fenestrated expansions. Cells placed biserially, or alternate, so as to form branches or 'interstices,' similar in many respects to the Genus *Scrupocellaria* among living Polyzoa: cells bladder-like, margin of mouth raised and covered (?) by 'operculum' during the life of the animal. The nearest living representative cell among the British Polyzoa figured by Hincks[1] is that of *Alcyonidium albidum*, with which I can compare generally the cells of the *Fenestellidæ*. The following genera are grouped provisionally, many details having yet to be worked out:—

Genus I. FENESTELLA—*plebeia*, *polyporata*, *membranacea*, in which the cells are biserially placed.
,, II. FENESTELLINA—*nodulosa*, *actinostoma*, in which the cells are alternate, literally forming single rows.
,, III. GLAUCONOME—Only some of the species studied.

Fam. II.—POLYPORIDÆ.

Primary Char.—Polyzoary forming small and large fenestrated expansions. Branches robust, cells placed contiguously in a slanting direction over the branch, opening on one side only; the cells on the margins of the branches (younger cells) nearly of the same shape as in the *Fenestellidæ*; the older cells in the innermost portion of the branches much compressed, but never partaking of a tubular character.

Genus IV. *Polypora.*

The cell-structure of the following genera is such as to warrant their separation from the whole of the above genera, but they are not sufficiently studied, neither are their details so well worked out as to enable me to suggest a proper place for them at present.

Genus I. *Goniocladia*, Etheridge, Jun.
,, II. *Synocladia*, ,, ,, } Two *most* distinct
Synocladia, Young and Young. } species.
,, III. *Hyphasmapora*, Etheridge, Jun.
,, IV. *Thamniscus*, Young and Young.
,, V. *Sulcoretepora Robertsoni*, Young and Young.
,, VI. *Archæopora*, De Koninck.

All the above are types of distinct genera, and before they can be properly placed the Silurian, as well as the Permian Polyzoa must be carefully studied in the way that I have already suggested.

For the present, too, I will catalogue the remainder of the Carboniferous Genera, reserving for the future more detailed arrangements.

[1] *Brit. Marine Polyzoa*, 1880, p. 500; vol. i. p. lxx.; vol. ii. figs. 8 to 10.

Genus VII. *Rhabdomeson*, Young and Young.
,, VIII. *Ceriopora*, Morris.
,, IX. *Berenicea*, M'Coy = *Ceramopora*, Hall.

I thus, for the present, conclude my report on the British species of Carboniferous Polyzoa. It would have been comparatively easy for me to have made it longer—it would have been difficult indeed to have made it shorter. To the Palæontologist the study of the Palæozoic Polyzoa opens up many very important biological details, for the connection of the Polyzoa with the Graptolites is a question that must be dealt with in detail; and the relationship of the Palæozoic to all other Polyzoa must be grappled with intelligently and dispassionately; and for this purpose members of the Association could help either myself or others by furnishing materials for the study.

Report of the Committee, consisting of Dr. J. EVANS, Professor T. G. BONNEY, Mr. W. CARRUTHERS, Mr. F. DREW, Mr. R. ETHERIDGE, Jun., Professor G. A. LEBOUR, Professor L. C. MIALL, Professor H. A. NICHOLSON, Mr. F. W. RUDLER, Mr. E. B. TAWNEY, Mr. W. TOPLEY, *and* Mr. W. WHITAKER (*Secretary*), *for carrying on the 'Geological Record.'*

SINCE the last meeting of the Association (at Sheffield) the fourth volume of the 'Geological Record' (for 1877) has been issued. The printing of the volume for 1878 has been begun, and some of the work for the years 1879 and 1880 has been started.

The following particulars of the published volumes may be of interest, as showing the extent of the work:—

The first, for 1874, pp. xvi. 397 (=413)	contains	over	2130	entries.
The second, for 1875, pp. xx. 443 (=463)	,,	,,	2360	,,
The third, for 1876, pp. xxii. 416 (=438)	,,	,,	2370	,,
The fourth, for 1877, pp. xxvi. 432 (=458).				

The volumes therefore average 443 pages and 2280 entries.

Sixth Report of the Committee, consisting of Professor HULL, the Rev. H. W. CROSSKEY, Captain D. GALTON, Mr. GLAISHER, Professor G. A. LEBOUR, Mr. W. MOLYNEUX, Mr. MORTON, Mr. PENGELLY, Professor PRESTWICH, Mr. PLANT, Mr. MELLARD READE, Mr. ROBERTS, Mr. W. WHITAKER, *and* Mr. DE RANCE (*Reporter*), *appointed for investigating the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from those formations.*

Lancashire.—At Bootle, near Liverpool, an important boring has been carried to a depth of 1304 feet by Messrs. Mather and Platt, for the Liverpool Corporation water-supply. The diameter is 25 inches to a

depth of 1000 feet, and 20 inches beneath that limit. The water-level stood at 50 feet from the surface in the bore-hole before pumping commenced. This level is about that at which water stood in the adjacent Bootle well, when not pumped some years ago. The character of the Pebble Beds is well seen in the quarry in which the old well is sunk, and in the large quarry higher up the hill, from which it is evident that the thickness of this division of the Bunter is not less than 1200 feet, instead of 600 to 800, as anticipated; the base of the Pebble Beds was found in the boring at 1039 feet, where the Lower Mottled Sandstone was first penetrated, the rounded 'millet seed grain' being specially characteristic. This structure is well seen in the Lower Mottled Sandstone of the Vale of Clywd. The Lower Mottled Sandstone in the Bootle boring becomes very hard and compact at 1228 feet from the surface, being cemented together by lime; but the grain, when the rock is broken up, is seen to be the same. For details of this boring and for facilities to inspect the cores I have to thank Messrs. Mather and Platt, of Salford Iron Works.

Last year I stated the hard compact sandstone met with in the Bootle boring at a depth of 1228 feet from the surface probably belonged to the Lower Mottled Sandstone. I also called attention to the rounded character of the fragments of the soft sandstones lying between the base of the Pebble Beds, which occurred at 1039 feet, and the top of the hard bed just described, and I further attempted to show that this rounded, or 'millet seed grain,' was present in the hard rock beneath, which is simply the softer sandstone cemented together by lime. The boring having failed to penetrate the hard rock, though carried to a total depth of 1304 feet, left a certain amount of doubt as to the correctness of my identification.

In February, 1879, I was unacquainted with any rock resembling the hard compact sandstone of Bootle; in May of the same year I was much interested to recognise it in a series of samples of cores shown me by Mr. Timmins of Runcorn (the contractor for the well-borings and other works now being put down at Winwick near Warrington). On going through the series of specimens occurring beneath the hard band, I had the satisfaction of finding that the hard band at Winwick is underlaid as well as overlaid by soft running-sand, with a millet seed grain, the whole series most certainly belonging to the Lower Mottled Sandstone. Beneath them are 49 feet of indurated mottled grey and dark marls, and calcareous bands, overlying good limestone, which appears to precisely correspond to the Upper Coal-measure limestones near Manchester, and the limestones proved in the Clayton Vale Boring described in the 'Trans. Manchester Geol. Soc.' 1879 by Mr. Atherton, the cores from which I had an opportunity of examining through the courtesy of Mr. Vivian, of the North of England Rock-boring Company. These coal-measure deposits occurring at a depth of only 340 feet or 113 yards from the surface, cannot but be regarded as a discovery of the highest commercial importance, as well as of scientific interest; for, looking to the westerly attenuation of thickness of the Coal-measures of South Lancashire, there can be little doubt but that the Manchester coalfield will occur at a less depth beneath the limestones than at Manchester, in which case a valuable and workable coalfield may lie under the London and North-Western Railway at Parkside, where a boring has also recently been carried out, and where the coal-measures have probably been reached at even a still smaller depth, but the par-

ticulars of which I have not as yet been able to find time to procure, it necessitating a visit to Crewe, where the cores are preserved.

The following is the journal of the Winwick boring:—

ft.	in.		ft.	in.	
		Moss	2	0	Drift.
30	0	Fine white sand	28	0	
127	5	Fine-grained sandstone	97	5	New Red Sandstone, 310 ft. 6 in.
172	6	Coarse compact sandstone, with 'millet seed' grain and red marl band	45	1	
182	0	Shaly marl	9	6	
201	0	Fine-grained (L.M.) sandstone	19	0	
212	0	Hard sandstone	10	0	
214	0	Sandy marl / Marl	2	0	
226	0	*Calcareous* sandstone	12	0	
252	6	Marl	26	6	
270	6	Large-grained sandstone	18	0	
276	6	Marl	6	0	
298	6	Soft white sand	22	0	
329	6	Soft brown sand	31	0	
340	6	Red sandstone	11	0	
351	6	Mottled grey marl	11	0	Upper Coal-measures, 33 ft. 6 in.
360	0	Dark mottled marl	8	6	
365	0	Hard brown sandstone	5	0	
369	0	Brown marl	4	0	
373	0	Variegated marl	4	0	
385	0	Marl	12	0	
396	0	*Limestone*	11	0	37 feet of limestones.
399	0	Marl	3	0	
408	0	*Limestone*	9	0	
412	0	Compact *limestone*	4	0	

The dip of the Pebble Beds in the neighbourhood is to the south-east and south, at low angles. In Nos. 1 and 2 shafts the strata consist of soft red moulding sand without pebbles, very easily worked. No. 3 shaft exhibits characteristic Pebble Beds, the current planes being covered with dark mica; the rock is hard and contains pebbles. No. 4 shaft, near the Spa Well, also is in undoubted Pebble Beds, though moderately hard, but contains many pebbles.

A drift, or level, is being driven to this shaft from the pumping station 1200 yards distant, which will doubtless throw much light on the structure of these sandstones. A powerful spring of water was met with in No. 4 shaft, at a depth of about 90 feet from the surface.

The level of the Parkside wells of the North-Western Railway will be about 110 feet, that of Winwick pumping station 125 feet, that of the Spa Well about 96 feet, that of the Dallam Lane Forge well about 43 feet. Between Golborne and Parkside the Pebble Beds occur dipping east; from Parkside to Spa Well they continue, but gradually change their direction of dip to south-east, as is well seen at Middleton Hall Quarry, near Spa Well. Had not this change of strike taken place the base of the Pebble Beds would have cropped out north of Winwick, instead of which they occupy a considerable tract around Golborne, and the thickness of triassic strata at Parkside would have been much less than at Winwick, $1\frac{1}{4}$ miles to the south, the strike of the rocks nearly coinciding in direction with a line drawn between the two wells.

Between the Winwick pumping station and Dallam Lane Forge,

$2\frac{1}{2}$ miles distant, this is not the case; the Pebble Beds at Hulme Delf, south of Winwick, dip south, or directly at the Dallam works. The dip varies in different quarries from 4° to 8°. Taking it at 4°, and the base of the trias at Winwick at 215 feet below O.D., and assuming the surface of the coal-measures beneath the trias to correspond to the amount of dip, the base of the trias could be carried down 1000 feet at Dallam Lane Forge, or 1215 feet below O.D., and 1258 feet below the surface.

The boring of which I gave details actually penetrated of this depth 880 feet, the lowest beds met with being 70 feet of soft Lower Mottled Sandstone, with the millet-seed grain, occurring immediately beneath (pebble-bearing) Pebble Beds, so that these soft beds evidently belong to the uppermost portion of the Lower Mottled series. These we have seen at Winwick reach a thickness of more than 200 feet, and at Bootle boring of more than 300 feet, in the latter case without their base having been reached, so that they may possibly be 350 feet thick under Warrington, in which case their base will be 1230 feet beneath Dallam Lane Forge, which closely agrees with the calculation of the probable position of the base of the trias, based upon the observed dips at Winwick. There is therefore strong evidence to believe that the coal-measures underlie Warrington at a depth of 400 yards, but at what angle and in what direction they dip there is no evidence to show. The highest coals of the Wigan coalfield, the 'Ince Mines,' are striking nearly south, between Town Green, Ashton, and Edge Green, Golborne; and did no fault intervene, their southern prolongation would pass through Newton Bridge and Great Sankey, but it is repeatedly thrown back westwards by faults, with westerly downthrows, so that the coal-measures between Winwick and Sutton, are entirely measures lying above the Lyons Delf of St. Helens, and probably in great part belong to the Upper or Manchester coalfield. In the centre of this tract a colliery has been sunk at Bold Moss, east of St. Helen's Junction, for opportunities to view which, and for copies of the sections passed through, I have to thank Mr. Harbottle, the managing director. Several coal-seams have been passed through, and these have been supposed to be identical with the upper seams of the St. Helen's field; but after having the section drawn to scale, and compared with the neighbouring collieries, I am inclined to think that these coals are on a higher horizon, and probably belong to the Upper coal-measures. Progressing westwards the first fault with an easterly downthrow is that passing through Whiston, which, with that passing Sutton Heath, throws in the remarkable trough of New Red Sandstone, extending from Rainhill to Eccleston Hill, which I have lately had the opportunity of examining in great detail; and it will be noted that it is in this triangle that the small tract of Upper coal-measure limestone is brought by faults to the surface at Huyton, long since described by Mr. Binney and Prof. Hull. Here we have the normal south-west and north-east strike of this area, and should this continue eastwards, and the limestones proved at Winwick range in this direction with a south-easterly dip, the measures underlying the trias of Warrington must be very considerably above the horizon of the limestones, and higher in the series than any coal-measures cropping to the surface in Lancashire. But should the limestones of Winwick belong to the same horizon as those of the Manchester coalfield, it is in the highest degree probable that another 600 feet, and possibly much less, would reach the *Openshaw coal*, or its equivalent.

The soft 'millet-seed'-grained moulding sands of Town Green near

Ormskirk belong to the Upper Mottled Sandstone, but occupy a lower horizon in it than the more compact sandstones faulted in west of the railroad, in which the principal well-borings of the Southport Waterworks have been carried. But the soft beds afford the water-bearing horizon, in the wells of the Widness Local Board, at Stocks wells and Netherley.

For similar facilities I have to thank Mr. Beck, of Dallam Lane Forge, Warrington, for a boring made at that place. From an inspection of the cores, in company with my colleague, Mr. Strahan, we constructed the following journal:—

			feet.	
	1.	Boulder clay and drift	30	Upper Mottled Sandstone.
	2.	Red and pale yellow, soft rock . . .	350	
	3.	Red and white ditto, slickensides . . .	2	
384 feet.		FAULT.		
	4.	Flaggy micaceous sandstone	218	
		Red sandstone and thin shale bands . .		
600 „		Micaceous flags and slickensides . . .		
	5.	Red and white sandstone	159	
752 „		FAULT.		
	6.	Red Sandstone with pebbles	58	Pebble beds.
887 „	7.	Soft Red Sandstone	70	Lower Mottled Sandstone.

The water pumped was found to be salt:—

At a depth of	227	feet	from surface	40	grains	of salt	per gal.
„	345	„	„	170		„	„
„	390	„	„	300		„	„
„	445	„	„	750		„	„
„	500	„	„	1246		„	„
„	600	„	„	1575		„	„
„	680	„	„	3100		„	„
„	756	„	„	4000		„	„
„	818	„	„	4500		„	„

At Dallam Lane Forge boring, as stated above, distinct traces of a fault occur at 384 feet, and at 752 feet, and Mr. Beck found the beds in his opinion turned on end in the former. That one fault occurs ranging up from the south side of the river is undoubted, and I was inclined with others to attribute the brine spring met with to the action of this fault, leading the brine from the salt district in the Keuper Marls to the south. But during the past year, after careful study of the action of faults on the passage of water, I have given up this position as untenable.

Where two porous permeable rocks are thrown against each other by a fault, the dislocation offers little resistance to the passage of water through the faults, and affords no facilities for its passage along its length, either between its walls or along the face of the upcast slope.

Where two impermeable beds of shale or clay are thrown against each other, the fissure of the fault is narrow, so that it seldom includes foreign material, and water can neither pass through nor along it.

Where permeable formations are thrown against impermeable rocks, by faults, the district is divided into watertight compartments; water flowing down the dip planes of the strata, ponding up on the dip side, travels along the face of the fault, and rises until it escapes where the porous rock crops to the surface, and is cut off by the fault, the course of which is marked by a line of springs.

In the case of the fault traversing Warrington from the south, the fissure of the fault in the salt-bearing marls would be close, and unavailable as a duct, and supposing even brine-laden water to have sunk into the sandstones beneath, these being porous would not absorb it equally in all directions, and would be incapable of conveying it, in the fissure of the fault, to their outcrop to the north, under Warrington.

Looking to the probable proximity of the coal-measures to the surface, and that salt-springs occur in many coalfields, and, indeed in the Wigan coalfield, near Worthington, I am inclined to believe the brine-springs of Dallam Lane to be of coal-measure origin.

APPENDIX I.—*Borings in Lancashire Trias, collected by* C. E. DE RANCE, *Assoc. Inst. C.E.*

Boring executed by the North of England Rock-boring Company, Mr. Vivian, C.E., Manager, at Mr. James Hull's brewery, Preston, 1880. Surface about 105 feet above the Ordnance Datum line.

		ft.	in.
WELL, probably in Middle (Glacial) Drift	Middle Drift 58′ 6″	45	6
Muddy sand and clay . . .		4	6
Fine gravel and sand . . .		3	6
Hard sand		6	0
Dry muddy sand		6	6
Hard brown 'pinnel' . . .	Equivalent of Lower Boulderclay 23′ 6″	2	6
Brown sandy 'pinnel' . . .		3	0
Hard dry sand		3	0
Hard dry muddy sand . . .		4	0
Red sand		4	6
Hard red sandstone		7	0
Red sandstone		8	0
Soft red sandstone		3	6
Light red sandstone (O.D. level occurs, in upper part)		8	6
Red sandstone, very full of mica		23	6
Red and grey sandstones, mixed, full of mica . .		14	0
Red sandstone		15	7
Soft red sandstone		7	1
Coarse red sandstone		30	9
Red sandstone		17	2
Pink shale		5	0
Red sandstone		9	3
Rough red sandstone		14	6
		246	10

The water in this bore-hole rises within 40 feet of the surface, and its level is stated not to be connected with that of the water, in the well, derived from the Glacial Drift deposits. The rock passed through is a compact coarse sandstone, with occasional pebbles, micaceous partings, and thin shale beds, and it affords characteristic samples of the pebble beds of the Trias.

Southport Waterworks Co. Lim., per Mr. W. Harper, Secretary.

Information arranged and notes by C. E. De Rance.

1. Aughton, near Ormskirk. **1*a*.** 1867. Other bore-holes since well not deepened **3.** 180 ft., 10′ + 6′ 8″ oval, 4 bore-holes, 9·42 ft., 222 feet from surface. **3*a*.** One due west 100 yds., much water in fault.; one north 17 yds.; one south 20 yds. **4.** 110–112 ft., with constant pumping. The drift level, 144 ft. from surface, is not pumped down to with two engines. **4*a*.** Came to surface. **7.** No.

Per imperial gallon.

8. Actual and saline ammonia	0·004
Ammonia from organic matter	0·001
Nitrogen as nitrates	
Oxygen required to oxidise organic matter	0·010
Lime	5·544
Magnesia	2·474
Alkalies not ammonic	1·190
Chlorine	1·340
Sulphuric anhydride	2·114
Nitric acid	
Carbonic anhydride	5·893
Silica, aluminia, &c.	0·800
Hardness	18·0
Ditto after boiling	3·3

It is an extremely pure water.

C. MEYMOTT TIDY, M.A., M.B.,
Laboratory, London Hospital.

	ft.	in.		
9. Soil	1	0	40′ 6″	Well, 180′ 0″
Strong clay	6	0		
Sand and gravel	11	0		
Strong clay	12	0		
Quick sand	2	0		
Strong clay	8	6		
Red sandstone	139	6		
Ditto in bore-hole	42	0		
	222	0		

Fault with much water between Parliament Shaft and Pilot Shaft, cut in drift 10 to 15 feet from former shaft, and again in West drift from Pilot Shaft.

10. No. **11.** Are none. **12.** Yes. **13.** No. **14.** No. **15.** No.

Southport Waterworks Co. Lim., per Mr. W. Harper, Secretary.

1. Scarisbrick. **1*a*.** 1854; not deepened, and no bore-holes. **3.** 124 ft.; no bore-hole. **3*a*.** None. **4.** Not pumping, water stands near surface, and drains away into Old Quarry. **4*a*.** Same. **5.** Formerly pumped. **6.** No. **7.** No. **8.** Requires filtering through Mr. Spencer's Carbide.

Hardness 20° analysed by THOS. SPENCER, F.C.S.,
Euston Square.

	ft.	in.
9. Soil and clay	5	0
Freestone rock	115	0
	120	0

10. No. **11.** None. **12.** Yes. **13.** No. **14.** No. **15.** No.

Southport Waterworks Co. Lim., per Mr. W. Harper, Secretary.

1. Springfield, near Town Green. **1*a*.** 1876–9. Not completed. **3.** 232 ft. 15½′ × 6. Two shafts. **3*a*.** 135 ft. (39′ high, by 6′, then 15′ high). **4.** Always pumping, 125 ft. to water; when stopped, at surface. **4*a*.** At surface. **5.** Half-million gallons without lowering. **6.** Does not vary; new well. **7.** No.

8. Taken at 250 ft. from surface (bore-hole in well).

Per imperial gallon.

Actual and saline ammonia	0·001
Ammonia from organic matter	0·009
Nitrogen as nitrates	---

Oxygen required to oxidise organic matter	0·007
Lime	4·682
Magnesia	2·298
Alkalies not ammonia	0·920
Chlorine	1·440
Sulphuric anhydride	2·013
Nitric acid	—
Carbonic anhydride	5·123
Silica and alumina	0·100
Hardness	14·8
Ditto after boiling	5·1

The waters from four feeders at 100, 200, 210, and 225 feet from surface, contain less lime, magnesia, and sulphuric and carbonic anhydride.

The water is of very great purity. I obtained no evidence of organic nitrogen whatever.

C. MEYMOTT TIDY, M.A., M.B.,
Laboratory, London Hospital.

			ft.	in.
* 9.	Soil	ft. in. 79 0	1	0
	Sand		3	0
	Soily clay		5	0
	Gravel and sand		15	0
	Clay		16	0
	Gravel and sand (water)		1	6
	Sandy clay		15	6
	Sand and gravel		2	0
	Strong clay		5	0
	Sandy gravel		15	0
	Soft red sandstone in well		153	0
	,, ,, bore-hole		20	0
			252	0

Mr. Mason, Manager Southport Waterworks, Springfield Station.

Boring made by Mr. Mason, in field at Old Quarry, north-west of Town Green Station.

Soil	1	6
Clay	1	9
Sandy clay	8	6
Freestone	134	3
Very light rock	2	0
Blue rock	0	6
Red sandstone, soft	151	6
	300	0

Boring made by Mr. Mason, in field near Gerrard Hall, east of Town Green Station.

Clay	8	0
Gravel (water)	2	0
Red sandstone	290	0
	300	0

10. No. **11.** Are none. **13.** No. **14.** No. **15.** No.

* The section of these drift deposits has been published by Mr. G. H. Morton, F.G.S., in *Proceedings Liverpool Geolog. Soc.*, vol. iv. part iii. p. 370, 1879.

Mr. Arthur Timmins, Stud. Inst. C.E.

Boring executed in 1880 by Mr. J. Timmins, of Runcorn, at Burscough Bridge, for the Lancashire and Yorkshire Railway.

	feet
Glacial drift (sand and gravel)	240
Red marl	26
Loose rock	23
Solid red and brown sandstone, brown conglomerate at base	162
	451

The volume of water is stated by Mr. A. Timmins to have increased much on reaching the solid rock at 289 feet from the surface.

No section of the rock is visible very close to the boring, but as Upper Mottled Sandstone is seen both to the N.E. and S.W. of it, the rock first met with probably belongs to this formation, and is so represented on the map of the Geological Survey. These beds reach a thickness in the district of above 400 feet, and as the first 289 feet consisted entirely of drift, the upper beds here have doubtless been denuded away, and only about 111 feet would probably be left. The boring penetrated 185 feet of rock, consisting of red and brown sandstone, at the bottom of which was a coarse brown conglomerate, which is probably the conglomerate I found occurring at the top of the Lower Keuper Sandstone, near Orrel, east of Waterloo and north of Liverpool.

Well and bore-hole at the works of Messrs. Bayley & Craven, at Ayecroft, Pendleton, near Manchester. Well 32 feet deep, 6 feet diameter. From bottom 2 tunnels diverge, and extend about 50 feet, containing when full upwards of 500 cubic yards.

The bore-hole is 403 feet deep from the bottom of well; the first 312 feet is 18 inches' drain; the remaining, 91 feet 15 inches.

The whole depth is in New Red Sandstone, 403 feet.

This well yielded upwards of 5,000,000 gallons per day, on November 28, 1859.

Borings in the Trias and Permians of the Midland Counties, collected by C. E. De Rance, F.G.S.

Bore-hole at Allford Green, one mile east of Childs Ercall. Carried out for Mr. Reg. Corbet by Mr. A. Bosworth. Obtained by Mr. J. Dickinson, H.M. Inspector of Mines.

	feet
Red sandstone	400
" " with pebbles	180
Dark purple marl alternating with beds of red sandstone, 8 ft. to 40 ft.	320
Dark red, and a little blue marl	110
Alternating grey, brown, and red sandstone, with (coal-measure ?) plants	40
Conglomerate similar to that of Silverdale	10
	1060

Some further particulars of the Leamington Waterworks are given by Mr. G. B. Jerram, C.E., engineer.

The wells are situated on the north-east side of the town, at the foot of the Newbold Hills, about 214 feet above the level of the sea; the deepest boring is 248 feet deep, or 34 feet below it.

A 20-feet well is carried to a depth of 113 feet. An adjoining well,

7 feet 6 inches diameter, is down to 110 feet, and from it a tunnel about 6 feet high, to the other well. From the larger well a 20-inch bore-hole is carried down to 212 feet 6 inches from the surface. From the smaller well another 20-inch bore-hole is carried down to 210 feet from the surface, and with a 12-inch diameter to a further distance, in all 242 feet 6 inches from the surface.

The beds passed through by the wells consist of brown soft sandstone, with bands of white sandstone, hard rag, and marl partings. The bore-holes pass through hard red, white sandstone, with red marl partings, the last bed bored through being soft marl, with streaks of hard, 10 feet in thickness.

Borings in the Trias, on the north and south banks of the Tees, collected by C. E. De Rance, F.G.S.

The Triassic sandstones seen in the banks of the Tees, in the direction of Stockton, dip to the S.E., and the dip obtains in the Middlesboro' salt area, as the salt deposit was met with at a shallower level at Messrs. Bell's boring, north of that of Messrs. Bolckow & Vaughans. Still further north there is a local roll on the coast near Greatham, close to which there is a boring, $1\frac{1}{2}$ miles W. of Seaton Carew, 529 feet deep.

A bore-hole was put down in 1828 by Mr. Fletcher, at Oughton, about a mile north of Greatham, and two west of Seaton Carew. Details given by Mr. Peacock, C.E., 'Trans. Cleveland L. and P. Soc.,' 1880:—

			Thickness. ft.	in.
	1. Soil		1	0
	2. Gravel, with water		11	0
	3. Blue clay, very strong		27	0
	4. Sand, with a little water		1	8
	5. Blue clay, very strong		8	6
	6. Red sand		3	6
	7. Sandy clay		5	2
	8. Red sand		8	2
Drift.	9. Blue clay	136 0	3	10
	10. Sandy clay		1	6
	11. Sand, with a little water		0	8
	12. Clay, very strong, pebbles		24	0
	13. Grey freestone		2	0
	14. Grey sand		4	2
	15. Clay, very strong		1	9
	16. Clay brown, very fair		9	1
	17. Brown freestone		5	0
	18. Grey metal		7	5
	19. Brown post, with girdles		3	0
	20. Red stone		12	7
	21. White post, very strong, metal partings		5	4
	22. Grey metal		1	2
	23. Red freestone		4	1
	24. White post		3	2
	25. Red freestone		15	0
	26. Post girdles		0	9
	27. Red freestone		22	10
	28. Blue metal		3	6
	29. Red freestone		11	6
	30. Blue metal		2	0
	31. Red freestone, post		6	0
	32. White post girdles		0	6
	33. Blue metal		1	6

	Thickness ft.	in.
34. Red freestone, post	13	0
35. White post girdles	0	6
36. Red freestone, post	8	6
37. White post	6	0
38. Red metal	12	0
39. White post girdles	0	6
40. Red freestone, post	6	0
41. White post	0	6
42. Red freestone, post	17	2
43. Whin girdles	0	4
44. Red freestone, post	17	2
45. Strong whin girdles	0	2
46. Red metal	2	0
47. Strong whin girdles	0	8
48. Red metal	3	0
49. Strong brown post, with metal partings	4	0
50. Red metal	6	0
51. Grey metal	3	2
52. Red freestone, post	17	6
53. Red bastard whin	0	10
54. Red metal	0	2
55. Strong whin girdles	0	8
56. Red metal	9	0
57. White post girdles	0	4
58. Red metal	13	8
59. White post girdles	0	2
60. Red metal and white	6	2
61. Red metal	1	6
62. White post girdles	0	8
63. White stone, resembling spar	0	4
64. Red metal	0	4
65. Bastard whin girdles	0	6
66. Red metal	0	2
67. Bastard whin girdles	0	5
68. Soft red freestone, metal partings	3	6
69. Red metal	1	6
70. Red freestone, post	2	7
71. Red metal	0	4
72. Brown freestone, post	15	8
73. Red metal	0	8
74. White post	1	1
75. Red metal	0	6
76. Brown freestone, post	6	6
77. Red metal	0	6
78. White post	2	0
79. Red metal	0	4
80. Brown freestone, post	2	0
81. Red metal, very strong	1	0
82. ,, ,, soft	1	2
83. Brown freestone, post	3	10
84. Red metal	0	8
85. Brown freestone, post	3	4
86. Red metal, strong	1	6
87. ,, ,,	0	6
88. Strong brown post, with feeder of water	3	0
89. White post girdles	0	2
90. Red metal	1	0
91. White post girdles	0	10
92. Red metal, with post girdles	14	4
93. Strong brown post	3	0
94. Red metal, 329 ft. 9 in.	0	4
95. COAL	0	4

		Thickness ft.	in.
96.	Red metal	1	0
97.	" strong	6	0
98.	Strong freestone, post	6	6
99.	Soft red metal	0	3
100.	Brown whin	1	2
101.	" freestone	0	10
102.	" whin	5	4
103.	" freestone	0	7
104.	" whin	5	7
105.	White stone, resembling spar	0	3
106.	Brown freestone	2	9
107.	" whin	2	6
108.	Strong white post	4	0
109.	" whin post	1	1
110.	White whin	0	1
111.	Strong white stone	3	11
112.	" grey post	1	6
113.	" blue post	0	6
114.	Blue metal	1	3
115.	Brown stone	6	7
		517	9

Boring at Old Brewery, Norton Street, Stockton. Geological Survey Sheet 50 Durham :—

	Fm.	ft.	in.
Made ground	0	1	2
Black sand	0	4	10
Light-coloured sand	0	2	10
Loamy clay	5	2	6
Brown strong clay	1	0	6
Dark sand	1	4	0
Brown strong clay	3	2	4
Sand, with water	0	3	0
Clay, with stone	2	0	0
Yellow freestone	0	2	6
Rough gravel under	0	1	6
Hard red sandstone	4	1	0
Red sand and mould	2	3	6
Soft red metal	1	0	0
Hard red sandstone	5	5	6
Soft red metal	1	4	6
Hard red shale	1	5	4
	33	2	2

Section by Mr. John Marley, C.E. Sunk through New Red Marls to the Permian, commenced July, 1859. Diameter, 1 foot 6 inches. Boring ceased August 29, 1863, at Bolckow & Vaughans', Middlesbrough.

Depth ft.	in.		Thickness ft.	in.
11	0	Shaft:—made ground	11	0
19	0	Dry slime or river mud	8	0
29	0	Sand with water	10	0
39	0	Hard clay (dry)	10	0
40	0	Red sand with a little water	1	0
43	0	Loamy	3	0

Depth ft.	in.		Thickness ft.	in.
58	0	Hard clay (dry)	15	0
69	0	Rock mixed with clay and water	11	0
70	0	„ dry	1	0
76	0	„ gypsum	6	0
78	0	Gypsum and water	2	0
133	0	Red sandstone, with veins of gypsum	55	0
139	0	Gypsum, with clay	6	0
140	0	Brown shale, with water	1	0
144	0	Red sandstone	4	0
156	0	„ „ with small veins of sulphate of lime	12	0
159	0	Blue posts stone, with water in both	3	0
178	0	Red sandstone, with water	19	0
615	4	*Boring*:—Red sandstone	437	4
616	10	Red and white „	1	6
832	5	Red sandstone	215	0
833	5	„ „ and clay } 130 feet.	1	0
885	8	„ „	52	3
894	8	„ „ and clay	9	0
961	1	„ „	66	5
963	10	Strong clay	2	9
965	4	Red sandstone	1	6
992	9	Red sandstone	27	5
1001	9	Red sandstone and clay	9	0
1051	1	Ditto, with seam of blue rock $1\frac{1}{4}$ inch at 1005	49	4
1052	6	Red and blue sandstone	1	5
1058	6	Red sandstone	6	0
1059	11	Red sandstone, and thin veins of gypsum	1	5
1099	7	„ „ „	39	8
1100	9	Red and blue clay and gypsum	1	2
1188	0	„ „ with veins of gypsum	87	3
1191	2	Gypsum	3	2
1191	10	White stone	0	8
1194	6	Limestone	2	8
1194	8	Blue rock	0	2
1194	10	Blue clay	0	2
1195	8	Hard blue and red rock	0	10
1198	3	White stone	2	7
1199	5	Dark red rock	1	2
1206	0	Dark red rock, rather salt	6	7
1218	7	Salt rock, rather dark (i.) } 100·5	12	7
1222	8	„ „ very dark (ii.)	4	1
1226	2	„ „ light (iii.)	3	6
1253	6	„ „ rather dark (iv.)	27	4
1297	0	„ „ very light (v.)	43	6
1306	0	„ „ rather lighter (vi.)	9	0
1307	0	Limestone	1	0
1313	4	Conglomerate; this rock resembles limestone, and contains much salt	6	4

Analysis of Salt No. V.[1]

NaCl	96·65
$CaSO_4$	3·09
$Mg.SO_4$	·08
Na_2SO_4	·10
$Li.O_2$	·06
Fe_2O_3	traces
H_2O	0·4

[1] *Trans. N. of England I. of M.E.* vol. xiii. p. 10.

I have to thank Mr. Allison, of Guisborough, for a section of strata bored through by the Diamond Drill Co., Saltholme Farm, on the Durham side of the Tees, for Messrs. Bell, Bros., December 15, 1874.

No.	Strata	Thickness ft.	Thickness in.	Depth ft.	Depth in.	Remarks
1	Soil	1	6	1	6	
2	Clay	4	0	5	6	
3	Dark sand	7	6	13	0	
4	Clean sand Drift, 77·0	26	0	39	0	
5	Red clay	3	0	42	0	
6	Sand and gravel	8	0	50	0	
7	Boulder clay	27	0	77	0	
8	Red marl	73	0	150	0	
9	Red sandstone, with veins of marl . .	144	0	294	0	
10	White sandstone	1	3	295	3	
11	Red sandstone, with veins of marl . .	153	9	449	0	
12	Red sandstone	10	0	459	0	
13	Soft marl	3	0	462	0	
14	Red sandstone	6	0	468	0	
15	Blue vein	0	10	468	10	
16	Red sandstone	31	2	500	0	
17	Red sandstone, with veins of marl . .	27	0	527	0	
18	Soft marl	4	0	531	0	
19	Red sandstone	29	0	560	0	
20	,, ,, with veins of marl . .	49	0	609	0	
21	Soft marl	6	0	615	0	
22	Red sandstone, with veins of marl . .	31	0	646	0	
23	,, ,, ,, . .	6	0	652	0	
24	Marl, with blue veins and sandstone . .	17	0	669	0	
25	Red sandstone, with veins of marl . .	66	0	735	0	
26	Blue vein	0	7	735	7	
27	Red sandstone, with veins of marl . .	13	5	749	0	
28	Strong marl	9	6	758	6	
29	Red sandstone, with veins of marl . .	26	6	785	0	
30	Blue vein	0	3	785	3	
31	Strong marl	6	3	791	6	
32	Red sandstone, with veins of marl . .	30	6	822	0	
33	Strong marl and sandstone . . .	17	0	839	0	
34	Red sandstone, with veins of marl . .	16	0	855	0	
35	Strong marl	20	0	875	0	
36	Red sand and marl	5	0	880	0	
37	Red sandstone, with veins of marl . .	14	0	894	0	
38	Strong marl, with veins of sandstone .	6	0	900	0	
39	Strong marl	23	0	923	0	
40	Strong marl, with veins of gypsum . .	7	0	930	0	
41	Mixed marl and sandstone . . .	27	0	957	0	
42	Marly sandstone, with veins of gypsum .	141	0	1098	0	
43	Gypsum	4	0	1102	0	
44	Hard white stone	3	9	1105	9	
45	Gypsum	3	6	1109	3	
46	Marly sandstone, very salt . . .	1	1	1117	4	
47	Decayed red marl, with salt . . .	10	3	1127	7	40 to 45 per cent. of salt, only 3 ft. core, fresh water being used.
48	Red rock salt	9	0	1136	7	
49	Rock salt	66	5	1203	0	
50	Salt, with marl and gypsum . . .	19	0	1222	0	

No.	Strata	Thickness ft.	in.	Depth ft.	in.	Remarks
51	Gypsum, containing salt	7	0	1229	0	
52	Soft shale, with salt and gypsum . .	7	0	1236	0	
53	Soft white shale	2	0	1238	0	
54	Gypsum and anhydrite	23	0	1261	0	
55	Magnesian limestone (liberation of gas) .	52	0	1313	0	
56	Grey limestone	15	0	1328	0	
57	Gypsum	8	0	1336	0	
58	,, containing salt	1	0	1337	0	
59	Rock salt	14	0	1351	0	
60	Marl, containing salt	2	0	1353	0	
61	Marl, with gypsum	1	0	1354	0	
62	Impure salt	1	0	1355	0	

A boring for coal was commenced in 1856, for Lord Falkland, in Kirklivington, and carried on in 1857 and 1858, under the superintendence of my friend Mr. P. S. Reid, M.E. :—

		ft.	in.	ft.	in.
1.	Reddish clay			27	0
2.	Fine sand			7	0
3.	Coarse sand			4	0
4.	Fine sand			10	0
5.	Reddish clay	Drift.		51	0
6.	Yellow sandstone	109	2	0	8
7.	White sandstone, hard			0	9
8.	Sand and gravel			4	0
9.	White sandstone			1	6
10.	Sand and gravel			3	3
11.	Light bluish sandstone			119	10
12.	White sandstone, extra hard . . .			0	11
13.	Light fire clay			1	5
14.	Light fake (Scotch for *shale*) . . .			2	6
15.	Red sandstone, in one bed			204	3
16.	Red fake and 'blae' (Scotch for sandstone)			1	0
17.	Red sandstone, hard			1	1
18.	,, ,, soft			18	0
19.	,, fake and blae			0	3
20.	Sandstone, extra hard			2	3
21.	Fake			7	3
22.	Sandstone, extra hard			2	6
23.	Fake			7	8
24.	Sandstone	76	3	4	0
25.	Fake			4	8
26.	Sandstone			2	1
27.	Fake and clay			2	8
28.	Sandstone			3	9
29.	Clay			0	7
30.	Light red sandstone.			1	9
31.	Red sandstone in bed			13	9
32.	,, ,, ...			3	0
33.	Magnesian limestone (?)			6	9
34.	Red fake			3	0
35.	,, fake and clay			8	8
36.	,, fire clay			9	5
37.	Magnesian limestone (?)			6	8
38.	Fake and clay			2	3
39.	Magnesian limestone			1	6
40.	Red fake and clay			5	1

		ft.	in.
41.	Sandstone, hard	9	1
42.	„ in bed	4	9
43.	Light red sandstone, hard	4	0
44.	Red sandstone, extra hard	1	4
45.	„ „ and beds of fake	6	4½
46.	„ shale with bands of red sandstone	16	2½
47.	Grey pyritic sandstone	1	0
48.	Red shale with beds of hard red sandstone	24	3
49.	*Gypsum*, (called 'chalk and pipe clay,' by men)	0	9
50.	Red shaly sandstone	6	9
51.	„ sandstone with a shaly appearance	20	6
52.	Shaly sandstone and gypsum	20	0
53.	Sandstone, with carb. and sulph. of lime	17	6
54.	Ditto	6	0
55.	Ditto	14	6
		710	0

Mr. Reid is of opinion that the beds 33, 37, and 39 are not truly referable to the magnesian limestone; Mr. Morley, C.E., however, considered these beds to belong to that formation, and the lower part of the boring to be in the Lower Permian Sandstone.

Still further west, two borings for coal were put down at Woodhead, near Great Smeaton, in 1789, by General Lambton, the one 396 feet deep, the other 444 feet.

The following section is given in the Geological Society's 'Transactions,' vol. iv. :—

Woodhead Borings, 1789.

	ft.	in.		ft.	in.
1.	24	9	Soil and brown clay	4	0
2.			Dark strong clay, with white boulders	20	9
3.			Red metal stone with grey girdles	48	0
4.			Red stone with white girdles	31	3
5.			Grey and white stone	4	0
6.			Gypsum, with flinty lumps	7	0
7.	116	6	Blue whin, with sulphur water	1	6
8.			Strong white post, whin girdles	6	6
9.			Bastard whin	12	0
10.	231	3	Strong white post with whin girdles	36	6
11.			Blue grey metal stone with white scars	8	0
12.			Gypsum	2	6
13.			Soft red stone	6	0
14.			Red and white post	19	0
15.			White post with red scars	18	0
16.			Red, white, and grey post, red partings	27	0
17.			Soft blue-grey metal	4	0
18.			Grey and white post	33	0
19.			Strong blue-grey stone	5	0
20.			Strong white and grey stone	60	0
21.	189	4	Whin	3	0
22.			Mixture, whin	9	0
23.			Strong white calcareous post and white girdles	99	4
				445	4

The 190 feet of white sandstone in the boring has been referred by some to the millstone grit, but probably belongs to the waterstone, as suggested by Mr. Peacock. He stated the sulphur spring met with in the boring,

used at Middleton Spa, was also found in a search for gypsum, in a boring at Ormesburg (Mr. Pennyman's lodge-gates,) near Middlesborough, in 1851, at a depth of 40 feet, the section being :—

	ft.	in.
Clay and sand	7	0
Red clay	14	0
Blue metal	3	0
Ironstone girdle	0	4
Blue metal, with sulphur water at 16 ft.	16	8
	41	0

Two miles north-west of the Woodhead boring at Eryholme, a boring was put down in 1809, by Mr. George Allan, M.P., of which the following account is given by Mr. Peacock :—

		ft.	in.
Sand	Drift, 34 ft.	12	0
Clay and cobble stones		16	0
Quicksand		2	0
Cobbles and sand		4	0
Red sand post (water)		60	0
Grey sand post		3	0
Ditto, rather hard clay following		121	0
Red soft sand post		3	0
Strong red post		300	0
Soft red post, not so red		12	0
Hard dark-red post		90	0
Clay and post		3	0
Red post		24	0
Flooring	Grey beds	1	0
Hard grey post		12	0
		666	0

Coatham Boring, 1867, (communicated by Mr. Peacock, M.E.) :—

			Depth ft.	Depth in.	Thickness ft.	Thickness in.
	1. Clay		6	0	6	0
Lower Lias.	2. Blue shale, with dagger band				39	0
	3. Nodular band				1	6
	4. Blue shale				1	8
	5. Nodular band				2	0
	6. Blue shale				6	4
	7. Nodular band				1	6
	8. Blue shale				21	0
	9. Bastard post grey				5	0
	10. Blue shale, with hard band				33	0
Rhætic.	11. Dark shale, with sulphuretted band		165	0	12	0
	12. White and grey post, with water (*brine*)				9	0
	13. Red and white mottled post, and blue and white				12	0
	14. Dark blue metal, with whin girdles				19	0
	15. White shale		223	0	18	0
Keuper Marl.	16. Red marl, mixed with gypsum	118 6			74	0
	17. Whin band				0	2
	18. Red marl				23	0
	19. Whin band				0	3
	20. Red marl, strong				7	0
	21. Gypsum				1	4
	22. Red marl		341	6	0	9

Works for the manufacture of salt formerly existed at Tod Point; but, Mr. Peacock states, whether sea water or the brine spring from the sea was used, is doubtful. About 1856, a 6-feet shaft was sunk on the marsh near Coatham, by the late Mr. Slate, of Redcar, in a fruitless search for coal; a strong brine was met with, to find which, the above boring was put down, but the brine spring met with did not realise expectation.

This boring is valuable as showing the actual junction of the lias and marls with gypsum, which latter, as pointed out by Mr. Peacock, are 28 yards thick in the Middlesboro' boring. The limestones, thick salt-beds, and gypsum in that boring, are probably referable to the Permian; the intervening beds of red sandstone, 673 feet, are probably referable to the Water Stones and Lower Mottled Bunter, the Upper Mottled and Pebble Beds having thinned out.

It would appear that a gradual overlap eastwards takes place in all the Triassic strata, along a north-east and south-west line, the more marked transgression being that at the base of the Keuper Water-stones, and at the base of the Pebble Beds of the Bunter, lines of extensive erosion occurring at the base of the Keuper building stones and conglomerates, and on the base of the Pebble Beds of the Bunter. The great thickness of these Triassic deposits in the north-west, is proved by these borings, and their thinning out to the south-east is established, and has an important bearing on the depth to concealed coalfields as well as on the water-bearing capacity of the Triassic sandstones.

Nottinghamshire.—Prof. Hull, F.R.S.

Retford.—2 wells in breweries, with good supply, 6 feet from surface, 600 feet in Keuper marl in the Bunter series.

Mr. C. Tomlinson, C.E., Rotherham.

Section of strata at boring of Retford Coal Co.'s boring at East Retford, Notts:—

	ft.	in.
Soft red marl and sandstone	11	6
Red and grey marlstone and grey pumice	30	6
Red sandstone	123	0
Grey and red marl	3	0
Red sandstone	92	6
Red sandstone and gravel	1	6
Red sandstone	230	0
Red marl and gravel	1	6
Red sandstone	142	6
Pebbles or conglomerate	8	0
Red sandstone	70	0
Red marl	3	0
Red sandstone	69	0
Red and grey marl mixed with red and white sandstone	99	0
Red marl and limestone	7	0
	902	0

Devonshire.—Mr. Thos. S. Stooke, C.E., Shrewsbury.

Bridge Mills, Silverton, South Devon.

Information obtained January 1879, yield about 315,000 in twenty-four hours. Strata passed through:—

Sand	about 94 ft.	
Rock	27	
Marl	29	
Clay and greensand	30	
Gravel	5	water
Hard clay	16	
Rock	16	
	217 ft.	

Approximate height above sea 80 or 90 feet.
No analysis further than to prove it was entirely free from iron.

Sussex.—Mr. W. Topley, Assoc. Inst. C.E., F.G.S.

SUB-WEALDEN BORING.

	ft.	in.
Alluvial deposit	16	0
Alternating calcareous beds and shales	160	8
Soft shaly sandstone, nodules and flints	16	0
Soft sandy shale	7	4
Soft whitish sandstone	52	0
Soft sandstone, darker	5	0
Sandy shale	17	0
Kimmeridge clay	154	0
„ more compact	44	0
„ softer	23	0
„ solid	26	0
„ with traces of carb. lime	20	0
„ dark brown veins	66	0
Brown limestone	1	6
Kimmeridge clay	3	0
Brown limestone	6	6
Kimmeridge clay	27	0
„ „ vein of carb.	40	0
„ „ very limy	21	0
„ „ veins of carb. lime, fossils	24	0
Kimmeridge clay „ „	57	0
„ „ „ „	19	0
„ „ veins of carb. lime	10	0
„ „	72	0
„ „ hard bands of limestone	57	0
„ „	16	0
Oxford clay, vein of carb. lime	28	0
„ „ hard, and more limy	9	0
Sandstone very soft, and vein of lime	12	0
Sandstone, shaly, full of fossils	41	0
Sandy shale, full of slip	2	0
„ „ more compact	17	0
„ „ limestone nodules	28	0
Shaly sandstone	37	0
Sandstone very shaly	8	0
Shaly limestone	27	0
Light blue limestone	4	0
Shaly limestone	14	0
Calcareous shale	28	0
„ „ free from sand	26	0
Clayey shale	19	0
Calcareous shale	21	6
Soft dark gritty limestone	28	6
Calcareous shale	20	0
Friable calcareous grit	17	0
Soft cal. grit, beds of lime	24	0
Calcareous limestone	4	0
Blue limestone and shale	27	0
Strong blue shale, few fossils	19	0
Strong blue shale	4	0
Limestone	10	0
Calcareous shale	36	0
Blue shale, few fossils	11	0
„ „ traces of encrinites	87	0
Calcareous shale, hard bands of lime	88	0
Light blue lime	10	0
Calcareous shale and fossils	9	0
„ „ hard lime	27	0
Soft dark shale, many fossils	59	0
Strong dark shale	12	0
Hard grey lime	17	0
Dark sandy shale	26	0
Dark shale	12	6
„ „	81	6
	1905	0

APPENDIX II.—*Information collected by Mr. James Plant, F.G.S.*

[The Questions to which the following are Answers will be found in the Sheffield Report, 1879, p. 161.]

Leicestershire.—Messrs. Corah & Cooper, St. Margaret's Works, Leicester.

1. St. Margaret's Works, Leicester. **1***a*. 1876. No. **2.** 200 ft. **3.** Well 26 ft. deep. Diameter 3 ft. 6 in. Bore 58 ft. deep. Diameter, 4 in. **3***a*. None. **4.** 72 ft.

before, 58 ft. after. Level restored in 1 hour. **5.** About 150,000 gallons in 24 hours. **6.** Not known. **7.** Not known. Water stands about 6 ft. below neighbouring canal. **8.** Hard, but very clear.

	ft.	in.
9. Drift, gravel, and soil	10	0
Upper Keuper marls	48	0
Upper Keuper sandstone	26	0
	84	0

Several layers of sandstone are very hard, others soft. Bore ends in 'running sand' upon which the auger makes no impression. **10.** None. **11.** Yes. **12.** No. **13.** No. **14.** No. **15.** None.

Messrs. Scott & Sons, Bay Street Mills, Leicester.

1. Bay Street Mills, Leicester. **1***a*. 1860. **2.** 200 ft. **3.** Bottom of well 45 ft. 4 ft. diameter to bottom of bore-hole, 70 ft.; 4 in. diameter. **3***a*. None. **4.** 15 ft. from surface. Sinks 20 ft. after pumping. **4***a*. 50 ft.; now 60 ft. **5.** Over 100,000 gallons in 24 hours. **6.** Not known. **7.** Not known; stands about 8 ft. below canal near. **8.** Very hard.

	ft.
9. Drift clay, gravel	12
Upper Keuper marls	36
Upper Keuper sandstone	22
	70

10. Yes. **11.** Yes. **12.** None. **13.** None. **14.** None. **15.** None.

Messrs. Jessop & Co., Engineers.

1. Friday Street, Leicester. **1***a*. 1876. No. **2.** 206 ft. **3.** 33 ft.; 4 ft. diameter. 37 ft. 4 in. diameter. **3***a*. None. **4.** 50 ft. before; 36 after. **5.** 100,000 gallons in 24 hours. **6.** Not known. **7.** Not known, stands about 10 ft. below canal. **8.** Very hard.

	ft.
9. Drift clay and gravel	12
Upper Keuper marl	38
Upper Keuper sandstone	20
	70

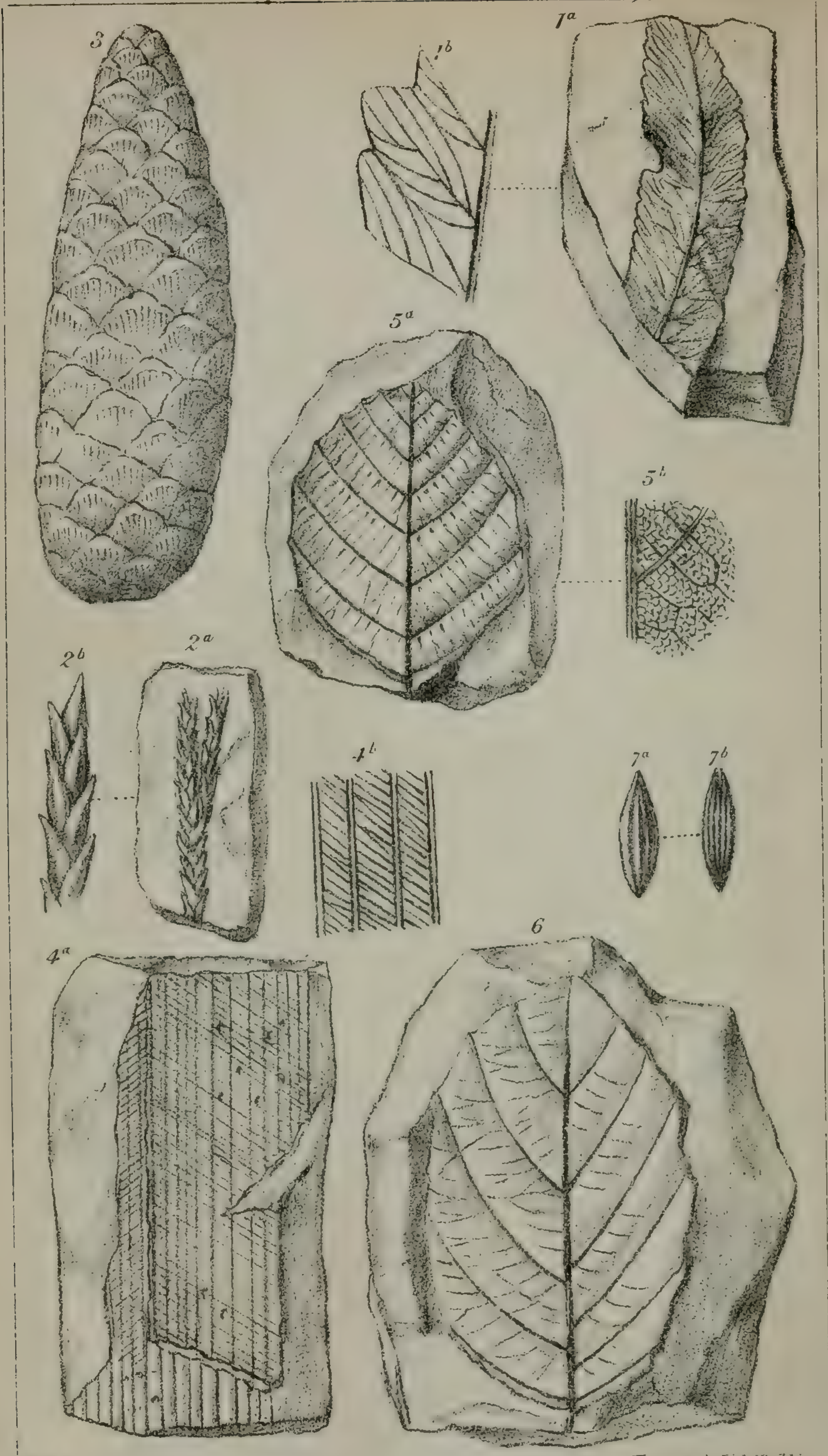
Bore ends in Upper Keuper sandstone. **10.** Yes. **11.** Yes. **12.** None. **13.** None. **14.** None. **15.** None.

Messrs. R. Walker & Sons, Manufacturers, Leicester.

1. Fleckney, Leicestershire. **1***a*. Many years ago. **2.** 400 ft. **3.** 45 ft.; 4 ft. diameter. **3***a*. None. **6.** Yes; diminished. **7.** Yes, affected by heavy rain. **8.** Very hard, but very abundant.

	ft.
9. Lias drift (contains large boulders of limestone much rolled)	30
Gravel and sand	15
	45

This is another instance of the large supply of water in connection with the Middle Lias (sand and rock) which lies about 2 miles S.E. of Fleckney, but at a *higher level.* **10.** Yes. **11.** No. **12.** None. **13.** None. **14.** None. **15.** No.



Illustrating the Report on the Tertiary (Miocene) Flora, &c. of the Basalt of the North of Ireland.

Illustrating the Report on the Tertiary (Miocene) Flora, &c. of the Basalt of the North of Ireland.

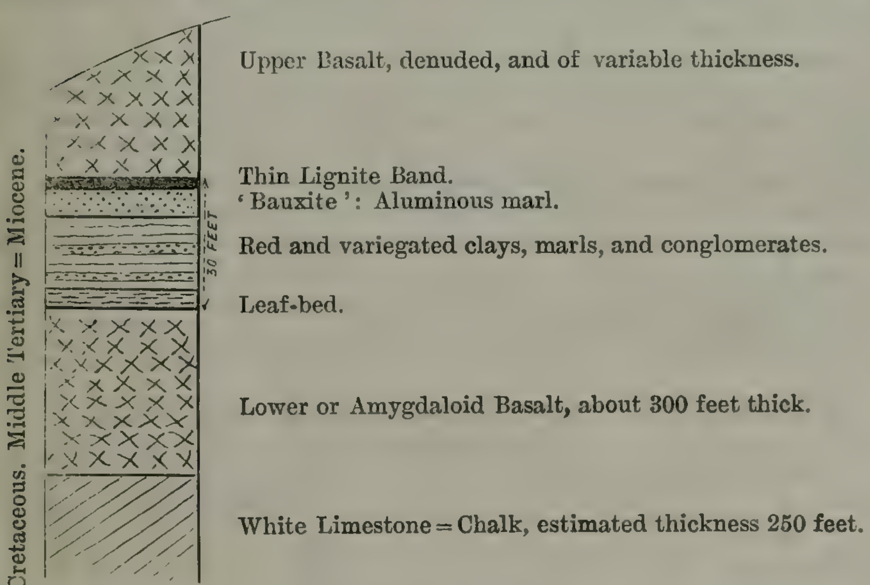
Second Report of the Committee, consisting of Professor W. C. Williamson *and* Mr. W. H. Baily, *appointed for the purpose of collecting and reporting on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland. Drawn up by* William Hellier Baily, *F.L.S., F.G.S., M.R.I.A. (Secretary).*

[Plates II. & III.]

Since the first report on this subject, presented to the Association at their last meeting in 1879, the Secretary, Mr. W. H. Baily, accompanied by assistants, has again visited the localities from which these interesting plant-remains were obtained, as well as some collections from the same places made by scientific gentlemen in the neighbourhood. He would especially mention William Gray, Esq., M.R.I.A., of Belfast; the Rev. Canon Grainger, D.D., of Broughshane; and Walter Jameson, Esq., Glenarm, manager of the Eglinton Chemical Works, Glasgow and Glenarm, who most obligingly afforded him every facility for carrying out his investigations.

To the last-named gentleman he is indebted for the following section of the Miocene deposits between the Upper and Lower Basalt at Libbert, one mile south of Glenarm, county of Antrim, who carried out the excavations there for the Eglinton Chemical Company, and to whose zeal and ability in the undertaking he is happy to be enabled to testify.

Section showing the Position of the Leaf-beds at Libbert, near Glenarm, County Antrim.—700 feet elevation above sea-level.



The series of Miocene deposits at this place was found to alter considerably on further excavation, the bauxite or aluminous marl being gradually replaced by pisolitic iron ore, accompanied by a different arrangement of the associated clays and marls.

This band of aluminous earth termed bauxite, which was alone sought

after by the Company for its value in certain manufactures, was entirely lost shortly after obtaining this section, although a whiter variety was discovered towards the base of these deposits, on making a further excavation in another direction.

The leaf-bed was found, as shown in the above section, at the base of this series of clays, marls, and conglomerates, proving by its fossil contents the entire series, including the basalt, to be of Middle Tertiary= Miocene Age. The deposit so designated is a light grey-coloured clay or marl, more or less arenaceous, and highly charged with plant-remains, most abundant amongst them being the branches of a *Sequoia*, which appears to be identical with the species found at Ballypalady, near Antrim, named by the Secretary of this report *S. Du Noyeri*, and which he considered to be intermediate between *S. Langsdorfii* and *S. Coultsiæ* (Heer).[1]

From the condition of these formations it would appear that they were the result of successive deposition on the shores of a lake, the iron-ore having probably been formed in deeper water. Under the boulder clay the Miocene marls were found to contain broken pieces of lignite, indiscriminately distributed through them, the plant-bed containing the remains of a terrestrial vegetation, which evidently flourished at or near the spot where they are now found, and from their complete state of preservation affording satisfactory evidence as to the character of that Flora.

Several additional specimens were procured at the extensive excavations still in progress for obtaining iron-ore, found in connection with the Miocene deposits at Ballypalady, on the Belfast and Northern Counties Railway, near Antrim. Amongst them are many impressions of fruits and seeds, which require closer examination, in order to their determination, than we have as yet been able to give them.

Other specimens have also been obtained from drifted masses of iron-ore found on the eastern shore of Lough Neagh, containing vegetable remains, evidently of a similar age, and which, from the condition of the deposits, are also in fine preservation. Some of these have been drawn, and added to the series of plates preparing for publication.

A series of the lignites found connected with these deposits and the silicified wood of Lough Neagh has been procured, which it is intended to examine microscopically by means of prepared sections.

In addition to the list of plants from these beds read before the Association in 1879, and published in the Report, we have to add the following:—

ADDITIONAL LIST OF SPECIES.—NORTH OF IRELAND.

PLANTÆ.

Fam. Cupressinæ.	
Taxodium sp.	Ballypalady, co. Antrim.
Abietinæ.	
Pinus Graingeri, n. s. (Baily)	,,
Taxinæ.	
Torellia rigida (Heer)	,, and Spitzbergen.
Salicinæ.	
Salix sp.	,,

[1] *Quart. Journ. Geol. Soc. Lond.*, vol. xxv. pp. 357, etc.

Cupuliferæ.	
Corylus McQuarrii (Forbes)	Lough Neagh, Island of Mull, and North Greenland.
Laurinæ	
Sassafras ? sp. . . . . A trilobed leaf, allied to living S. officinarum of N. America.	Glenarm.
Araliaceæ.	
Aralia Browniana (Heer)	Lough Neagh and North Greenland.
Magnoliaceæ.	
Magnolia glauca ? (Heer) cones	Ballypalady and North Greenland.

There are other leaves at present undetermined, which appear to belong to Ficus, Myrica, Cinnamonium, Olea, Fraxinus, and Laurus.

The entire number of species at present determined is about thirty; and of these, and others which may be yet identified, a more detailed description will be given when the plates are published.

Explanation of the Plates.

Plate II.

Fig. 1. *a, b.* Hemitelites Frazeri (Baily), shore of Lough Neagh. *b.* Portion of leaflet enlarged 3 diameters.

„ 2. *a, b.* Sequoia Couttsiæ (Heer), nat. size and enlarged, shore of Lough Neagh.

„ 3. Pinus Graingeri (Baily), cone, Ballypalady.

„ 4. *a, b.* Torellia rigida (Heer), nat. size and enlarged, Ballypalady.

„ 5. *a, b.* Corylus McQuarrii (Forbes); *b.* enlarged portion showing nervation and minute reticulation, Lough Neagh.

„ 6. Fagus-Deucalionis (Unger), Lough Neagh.

Plate III.

Fig. 1. Acer sp.	Glenarm.
„ 2. Fraxinus sp.	Glenarm.
„ 3. *a, b.* Viburnum Whymperi (Heer), *a.* leaf; *b.* fruit .	Ballypalady.
„ 4. McClintockia Lyallii (Heer), with twigs of Sequoia Du Noyeri	Glenarm.
„ 5. Juglans acuminata (A. Braun)	Ballypalady.

Eighth Report of the Committee, consisting of Professor PRESTWICH, Professor HUGHES, Professor W. BOYD DAWKINS, the Rev. H. W. CROSSKEY, Professor L. C. MIALL, Messrs. D. MACKINTOSH, R. H. TIDDEMAN, J. E. LEE, J. PLANT, W. PENGELLY, Dr. DEANE, W. MOLYNEUX, *and* Professor BONNEY, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by the* Rev. H. W. CROSSKEY, *Secretary.*

ALTHOUGH the destruction of Erratic Blocks is proceeding with remarkable rapidity throughout the country, the Committee are able to report the discovery and preservation of many important specimens during the past year.

Yorkshire.—Application has been made to the solicitors of the estate on which the Shap Granite Boulder near Filey, mentioned in the last Report of the Committee, occurs; and they have promised to draw the attention of the proprietor to it, so that, it is hoped, its preservation will be secured.

A remarkable block of Shap Granite, found at Seamer Station, near Scarborough, has been removed by the station-master into his garden, where it will be permanently preserved.

This is one of the finest and most remarkable blocks of Shap Granite yet observed; and Mr. J. R. Dakyns has favoured the Committee with the following report upon it:—

At Seamer Station, near Scarborough, a splendid boulder of Shap Granite is to be seen. This boulder measures roughly 5 ft. 8 in. × 4 ft. 10 in. × 4 ft. 3 in. It was found some years ago in quarrying a bed of gravel near the station for ballast. The boulder, as I am informed, was fairly imbedded in the midst of the gravel. This gravel is one of those described by Mr. C. F. Strangways [1] as forming 'a well-marked terrace, the summit of which is about 225 feet above the sea-level,' and as probably being the remains of an old raised beach. The gravel can still be examined, as the pits are still being worked alongside the railway near the station. It consists of horizontally stratified beds of dirty gravel and sand. At the S.W. end of the pit there is a thin wedge-shaped layer of stony clay in the midst of the gravel.

The boulder is specially interesting in this, that it is the only boulder of Shap Granite in the neighbourhood whose position in the beds is known; and, if the information is correct, this position shows that at the late age assigned to the gravels, ice must have been floating about, and dropping far-derived boulders here and there.

Lancashire.—Mr. John Aitken, of Urmston, near Manchester, reports that three boulders have recently been discovered in his neighbourhood, in addition to the very large one found at Old Trafford, about two years ago, and described by Mr. Binney in the 'Trans. Manchester Lt. and Phil. Soc.' (vol. xvii. p. 55).

[1] See 'Memoir of the Geological Survey.' Explanation of Quartz Shap, 95 S.W. and 95 S.E.

1. One at Lees Street, Piccadilly, Manchester, measuring 4 ft. 4 in. × 4 ft. × 3 ft.

2. One at Urmston, in the parish of Urmston, five miles west of Manchester.

3. One at Flixton, in the parish of the same name, seven and a half miles west of Manchester.

This measures 3 ft. × 2 ft. 8 in. × 2 ft. 1 in., but has been broken, and is said to have been originally half as large again.

All three are subangular; (1) and (2) are quadrilateral; (3) is somewhat conical.

They have numerous groovings and striations, although none are very deep, upon the flat sides.

The striations of (2) are diagonal at about 45°; and of (3) in a line with the longest axis.

The whole of these boulders, together with two others of lesser dimensions, consist of very fine highly siliceous grit rock, particularly (1) and (2), which almost become quartzites. They are all of a light bluish, fawny colour, (1) being of the darkest hue; are all compact, and do not exhibit any trace of lamination or bedding.

These boulders, together with the large one at Old Trafford, were found in almost one line, viz., roughly, E. and W.

No locality of derivation has yet been assigned to them.

They were disinterred from the drift, and are at the height of about 120 feet above the sea.

(1) is deposited in Alexandra Park, Manchester.

(2) is in a farm-yard at Urmston.

(3) is on the Red Lion bowling-green, Flixton.

Leicestershire.—The Committee are indebted to Mr. J. Plant for the following notices of erratic blocks in this county, in continuation of the observations which have been recorded in previous Reports.

Isolated Boulders.

Boulder at Aylestone, near the river Soar, two miles from Leicester.—Dimensions 4 ft. × 3 ft. 6 in. × 3 ft. It is subangular; the direction of the longest axis is N.E. by S.W., and it is without striations. It is composed of syenite, similar to that of Markfield, seven miles distant to the N.W., and there is no rock like it in the immediate locality. Long ridges of sandy gravel running S.E. occur near it, and it rests on sandy gravel.

Another boulder composed of the same rock occurs in the same locality. Dimensions, 3 ft. 10 in. × 2 ft. 10 in. × 2 ft. 6 in. It is also subangular, with the same direction of its longer axis, and without striations. It is 200 feet above the sea-level, and is situated at the N. end of long ridges of sand, which appear to be the *débris* of Upper Keuper Sandstone. It rests upon sand.

Boulder in the village of Thurnby.—Dimensions, 4 × 3 × 1 foot. Rounded and without striations. It is composed of granite similar to that of Mount Sorrel, eight miles distant to the N.W., and there is no rock like it in the immediate locality. It is about 600 feet above the sea-level, and rests on coarse gravel.

Another boulder of the same character occurs in a field near the same

village, half a mile more distant from Mount Sorrel, and about 620 feet above the sea-level. Dimensions, 2 ft. 6 in. × 1 ft. 6 in. × 1 ft. 3 in.

Boulder in the village of Bushby.—Dimensions, 1 ft. 6 in. × 1 ft. 3 in. × 1 ft. 3 in. Subangular, without striations; composed of granite similar to that of Mount Sorrel, eight and a half miles to the N.W.; no rock like it being in the same locality.

It is about 620 feet above the sea; is connected with a long sandy ridge, and rests upon sand.

Another boulder, precisely similar in character, occurs in the same village. Dimensions, 2 ft. × 1 ft. 9 in. × 1 ft. 4 in.

Boulder in Moody Bush field, New York farm, Syston.—This boulder can be seen in the field, on the left side of 'The Ridge Way,' one mile from its junction with the road from Barkby to Queniborough.

Its height above ground is 4 feet; depth in the ground probably between 3 and 4 feet. It is five-sided, the sides measuring as follows:—N.E. 1 foot 6 inches; N.W. 1 foot; S.W. 1 foot 6 inches; S. 8 inches; S.E. 1 foot 3 inches. It tapers gradually to the top, where its size is reduced to about one-half.

It is sharply angular, long-shaped, and put into the ground by human agency. The *longer axis* of the pentagon at the *top of the stone* points N. and S., shorter axis E. and W.

Deeply cut into four of the sides, in rude capitals, are the words 'Moody Bush.'

It is a very coarse ashy agglomerate from the old volcanic district on the N.W. side of Charnwood Forest, about 12 miles distant.

It is about 350 feet above the sea. It is isolated, but surrounded by deep drift deposits, and the bottom penetrates the Lower Lias clay.

Note on Moody Bush Stone.—This monolith, standing in a field on a very ancient road called 'The Ridge Way,' running S.E. to Tilton-on-the-Hill, is upon an elevation commanding a view of the surrounding country, for many miles on all sides, and may have served as a post of observation, or for a 'beacon fire,' or for communicating signals of other 'beacon fires,' for which evidence exists in this country at Borough Hill, lying due east 7 miles.

The monolith is remarkable for having its *longer axis* due N. and S. There is a tradition which says it was called 'Mowde Bush Stone,' and a former owner of one of the large estates near Mount Sorrel held a 'Court' at that place, called 'Mowde Bush Court,' and this landowner and his steward used to go to 'Mowde Bush Hill,' where the stone is, and cut a turf, which was brought into Court. The stone has been in its present position from time immemorial.

There is a general tradition also that it was usual for persons from neighbouring districts to bring a turf and put on it.

Boulder at Johnston's Farm, Thurnby, 5 miles from Leicester.—This block is in the corner of a field called Pol's Parlour, in a valley at the bend of the Willow Brook, W. of New Ingersby, and N. of Winkerdale Hill. Dimensions, 5 × 4 × 2 feet, but it extends several feet below the soil.

It is very rounded and worn, long-shaped, and the longer axis is N.W. by S.E.

It has probably been striated, but any striations that may have existed have been worn into holes by weathering. It is composed of Bünter conglomerate, or Permian breccia, and was probably derived from Barr Beacon, or Cannock Chase, distant 40 miles due west. It is about 450

feet above the sea-level, and is at the boundary of the parishes of Ingersby and Thurnby. It is connected with the Winkerdale Hill drift, and lies on deep sand.

Note on the New Ingersby Boulder.—This large ' erratic " undoubtedly stands at the boundary of two parishes, but I am inclined to think it is a mere accident; the stone has never been moved by man, but remains in the position it must have been originally left. It may at first have been buried deeply in the drift sand, as it lies in a hollow, and has been gradually uncovered by the washing away of this drift sand by the rain during past ages. On comparing it with specimens of ' Bunter Conglomerate' (obtained from this formation *in situ*), I have come to the conclusion that it probably belongs to that formation. The nearest point where this formation occurs is on the south side of the Ashby coalfield, distant about 25 miles, but from its coarse nature and the large-sized pebbles, I am inclined to think it must have come from ' Barr Beacon' or ' Cannock Chase.' It is in connection with great drift deposits which really form the ridges and hills of the surrounding district, which deposits we now know (from the cuttings of the Great Northern Railway, now in progress) to be upwards of 30 feet thick. It is quite possible (although its extreme hardness is against the idea) that this large block is a mass of very coarse ' pebbly drift' (some of the ' pebbles' are sub-angular), cemented by carbonate of lime and oxide of iron, and it may have been brought by ice from the N.W. side of the country, where beds of consolidated ' pebbly drift' of similar composition are known to exist. This source would be about 15 miles due N.W. The erratic is quite distinct in composition from the sandy clays and gravels that lie around for many miles.

(B.) Groups of Boulders.

On the estate of Sir A. B. C. Dixie, in the vicinity of the village of Market Bosworth, are eleven blocks, varying from rough cubes of 4 feet to 1 foot, the largest being about $4 \times 3 \times 2$ feet.

They are rounded, angular, and subangular.

Some of the group may have been removed from adjacent fields. They are composed of syenites and ashy agglomerates from Bardon Hill, Markfield, Clift Hill, and Groby, 7 to 8 miles distant. They are about 400 feet above the sea-level, and rest on the surface adjacent to drift beds.

In the village of Carlton are eight blocks of the same character, 420 feet above the sea-level. They do not appear to have been moved, but are scattered up and down the village.

In digging out a sewer in Victoria Road, Leicester, ten blocks were found together, 8 feet below the surface. They were rough cubes of 2 feet to 1 foot, sub-angular and angular; and composed of granite, syenite, mountain limestone, and chert, from Mount Sorrel 6 miles N., Breedon Hill 15 miles N.W., Matlock 30 miles N.W.

They were 290 feet above the sea-level.

In Rutland Street, Leicester, two boulders were found in making a sewer in boulder clay. Dimensions, $4 \times 2 \times 3$ feet and 3 ft. $\times$ 1 ft. 10 in. $\times$ 1 ft. 3 in. They were sharply angular, composed of the granite of Mount Sorrel, 6 miles N., 212 feet above the sea-level.

In a railway cutting near Countesthorp, Leicester, a group of boulders was found under a deep deposit of coarse gravel. The largest was 2 ft. 6 in. $\times$ 2 ft; the smallest about half that size. They were rounded. Three

blocks were Lower Keuper sandstone; two, oolitic limestone; one greenstone; two, white quartz (altered millstone grit). They were 400 feet above the sea-level, and spread over an area of about 20 yards. The group was derived from Nuneaton 14 miles W., Oakham 20 miles N.E., Hartshill, 15 miles W., Croft 4 miles W.

In the village of Oadby is a group of rounded blocks of granite from Mount Sorrel 9 miles N. The largest is $2 \times 1 \times 2$ feet; the smallest, 1 ft. 6 in. × 1 ft. × 1 ft. They are exposed on the surface, but may have been moved in making the road. They are 400 feet above the sea-level.

In Abbey Meadow, Leicester, in making the new river, a rounded boulder of chert, about 2 feet cube, was found. It was probably derived from Matlock, 30 miles to the N.W., and was about 120 feet above the sea-level.

In lowering a hill on the road near Aylestone, five blocks of syenite were found, the largest being 3 ft. × 2 ft. 10 in. × 2 ft. 8 in. They were sub-angular and angular; and derived from Groby, 5 miles to the N.W. They were 230 feet above the sea-level, and surrounded by sandy gravel.

At Lodge Farm, on the bridle road to Ridgeway, a group of boulders occurs; the largest being 2 ft. 6 in. × 2 ft. × 1 ft. 6 in.; the smallest, 1 foot cube. They are angular and subangular, and are scattered in a line for about 200 yards. They are composed of granite from Mount Sorrel, 5 miles off to the N.W., and are about 300 feet above the sea-level. They rest on the surface, but are in connection with a long ridge of drift.

Devonshire.—Mr. Pengelly favours the Committee with the subjoined Report respecting some very remarkable transported blocks and accumulations of blocks which he has observed in South Devon, the transportation of which it does not seem possible that the action of water alone could have effected.

I.—*The Granitoid Boulders on the strand between the Start and Prawle Points, South Devon.*

On July 25, 1865, Mr. W. Vicary and I observed two granitoid boulders on the strand between the Start and Prawle Points. They were well rounded, and totally dissimilar to any rock *in situ* in the district. The larger measured $36 \times 36 \times 16$ inches, and contained a considerable amount of granular schorl; the smaller one was nearly as large, of finer grain, and not schorlaceous.

The larger of these blocks cannot weigh less than ·75 ton. Their rounded forms may have been acquired since their lodgment on their present sites, as they must be exposed to the action of the waves at least every spring-tide storm. It is not improbable that the masses themselves may have been derived from submarine granitoid rocks *in situ*, at no great distance.[1]

II.—*The Block of Greenstone in the Village of Kingston, South Devon.*

Whilst passing through the straggling village of Kingston, nearly three miles, as the crow flies, S.S.W. from Modbury, South Devon, on September 28, 1877, I observed in the highway, very near a gateway leading to an adjacent dwelling-house, a 'greenstone' boulder, irregularly spindle-shaped, and measuring $4 \times 2 \times 2$ feet, and therefore weighing upwards of a ton.

[1] See *Trans. Devon. Assoc.* xi. 330–1.

There is a mass of greenstone figured on the map of the Geological Survey 2·6 miles long and ·6 mile in breadth, having its longest axis in an E. and W. direction, and extending from due north of Aveton Gifford to a point about a mile W.N.W. of Kingston, where it makes its nearest approach to the village.

III.—*The Blocks of Quartzite in the Parishes of Diptford and Morleigh, South Devon.*

On March 27, 1879, Mr. Paige-Browne, of Great Englebourne, near Totnes, wrote informing me that in a retired vale in the parish of Diptford he had recently found a 'clatter' of large stones, apparently quartzose, about two or three feet across, lying on moorish soil, and quite unlike the slaty rocks of the neighbourhood. They were very hard, and were broken up for the roads.

On October 3 we proceeded together to the immediate neighbourhood of Cleve farm-house, where Mr. Paige-Browne had observed the 'clatter.' Measured as the crow flies, the house is about 2·5 miles S.S.E. from Diptford village or 'church town,' and about 5 miles S.W. from Totnes. Adjacent to it, and on the north side, is an orchard; and on the north of that, a piece of waste marshy land bounded on the west by a small nameless stream, which divides it from a small wood or copse, and on the east by a parish road. This patch of marshy land, measuring not more than 100 feet from east to west, slopes for about 300 feet towards the north, where it enters a transverse valley, through which another small stream flows. On this waste land were the stones we had gone to see. They extended from the orchard hedge almost, but not quite, to the transverse valley; were half-buried in the soil; and it was obvious, from the number of large recent-looking pits which presented themselves, that many had been removed within a few weeks. Nevertheless, there was still a crowd of blocks, all of a very fine-grained compact quartzite, of a light grey or drab colour, many of them having quartz veins, and all utterly unlike the slaty rocks of the district. Most of them were subangular; some almost perfectly angular; whilst one was pretty well rounded. One, of ordinary size, measured $3 \times 2{\cdot}5 \times 2{\cdot}5$ feet, whilst another, perhaps the largest of the series, was $5 \times 2{\cdot}5 \times 2{\cdot}5$ feet. The smaller of the two must have weighed upwards of a ton, and the larger fully two tons. There were no such blocks in either of the small streams already mentioned, but their beds were in places covered with small stones derived undoubtedly from the same parent rock, and none of them were more than from 3 to 4 inches in length.

Mr. S. Jackson, of Cleve, informed us that within the last five years many scores of cartloads had been taken out of the piece of waste ground on which we were standing, for road-repairs; and he was of opinion that the same practice had obtained long before his time. We had observed, moreover, that corresponding blocks had been largely used in building rough walls and fences in the district.

Mr. Jackson also informed us that crowds of precisely similar blocks existed in various parts of the neighbourhood, and that a bed of rock of the same character was to be seen *in situ* in a quarry on Hannamoors, in the adjacent parish of Morleigh.

Blocks proved to be very numerous in the orchard at Cleve already mentioned, and Mr. Jackson stated that his experience led him to suspect

that in all the localities there were many more than were visible, as they were frequently met with completely buried in the soil, and about a foot below its surface. He added that he had never seen a specimen in the wood or copse immediately on the west, or, indeed, anywhere on that side of the small stream which divided it from the orchard and the waste land.

In an orchard on the New-well, or Newell, or Newill estate, about ·5 mile towards the S.E., they proved to be as abundant as at Cleve, and our guide, Mr. Jackson, stated that they were formerly quite as plentiful in an adjoining field on the Farleigh estate, but that the ground had been completely cleared. In a copse on the Farleigh grounds, and on the edge of a small stream, we saw a block in the form of a rectangular parallelopiped, measuring $8{\cdot}5 \times 5 \times 2{\cdot}5$ feet, thus containing upwards of 100 cubic feet, and weighing not less than 7·5 tons.

On Hannamoors, in the parish of Morleigh, blocks were very abundant, and many of them of considerable size.

From Cleve we had been continuously ascending, but not at a high gradient anywhere. At the highest, that is, the southernmost, point of Hannamoors there is a quarry in which, interbedded conformably with the ordinary soft slaty Devonian rocks of the district, there is a bed of quartzite, identical in character with the travelled blocks we had been studying, and of which it is no doubt the parent. This quarry is adjacent to the high road passing westward through the villages of Halwell and Morleigh to the town of Modbury, and occupying the crest of the hill on the northern slope of which all the blocks we had seen during the day were lying. We crossed this road a few yards west of the turnpike gate, about half a mile west of the village of Morleigh,[1] and almost immediately entered a quarry on the southern slope of the hill, where we found another exposure of the quartzite bed. Indeed, both quarries are worked to obtain the quartzite for the roads. The bed dips about 30° towards (true) S.E. nearly. So far as has been observed, the travelled blocks of quartzite existed only on the southern slope of the hill; they formed two parallel trains extending northwards, from near the ridge of the hill, along the distinct secondary valleys of Newell and Cleve; there are none on the minor north and south ridge, which divides the said valleys; the Cleve, that is, the western, train is the longer and reached the lower level; and, measuring as the crow flies, is about ·5 mile long.

There can be no doubt that the blocks had been transported from south to north, and from higher to lower ground. The gradient, however, is very slight, and, as almost all the blocks are very angular as well as large, it is difficult to suppose that their transportation was the result of nothing more than running water.

Should blocks be also found on the southern slope of the hill, they would not necessitate any further modification of the foregoing conclusions than the substitution of the words 'both northwards and southwards' for the words 'from south to north.'

None of the blocks we saw bore any scratches or traces of polish.

IV.—*The block of 'Greenstone' near Diptford Court, South Devon.*

Whilst passing through the parish of Diptford, on October 3, 1879, Mr. Paige-Browne and I observed by the roadside, near Diptford Court,

[1] See Ordnance Map.

about 5 miles, as the crow flies, S.W. from Totnes, a rounded block of 'greenstone.' It measured $4{\cdot}25 \times 2{\cdot}5 \times 2{\cdot}5$ feet, and, hence, contained nearly a cubic yard of stone, and must have weighed fully 1·75 ton. It was without traces of polish or scratches.

We had previously, and within the same hour, visited a quarry in a mass of igneous rock coloured as greenstone in the map of the Geological Survey. This mass is represented as extending nearly east and west for a distance of 1·7 mile, and having a maximum breadth of ·25 mile. The boulder, apparently of the same kind of rock, was upwards of ·5 mile due north from the nearest point of this mass. The map, however, indicates another, but smaller, mass of greenstone about the same distance north of the boulder.

V.—*The Limestone Block in the parish of Stoke-in-Teign-Head, South Devon.*

Having been informed by Dr. Midgley Cash, of Torquay, that he had observed a large stone in the parish of Stoke-in-Teign-Head, and near the road from Torquay to Teignmouth, I proceeded to inspect it. The block is a mass of limestone, lying on the road to Upper Gable, about 60 paces west of the Torquay and Teignmouth road, and is apparently used as a step by persons passing over the southern hedge into the adjacent field.

It may be described as wedge-shaped, with the angles and edges rounded. Each triangular face measures $3 \times 3 \times 1{\cdot}75$ foot, whilst the depth or thickness is 1·5 foot; so that it contains about 3·75 cubic feet, and weighs about 700 lbs., taking the specific gravity at 2·95.[1]

The extensive limestone quarries of Barton and Lummaton, in the parish of St. Mary Church, not more, as the crow flies, than 1·25 mile towards S.S.W., cause one to feel very sceptical as to the claims of this mass to the dignity of an Erratic Block. Nevertheless, it appears desirable to record its existence.

The Whitakers in the parish of Tamerton Foliot in South-western Devon.

On June 12, 1880, I accepted the invitation of Mr. F. E. Fox, B.A., F.R.G.S., of Uplands, in the parish of Tamerton Foliot, in the south-western corner of Devonshire, to inspect the 'Whitakers' abounding on his property.

The term 'Whitaker' is a provincialism. Mr. W. H. Marshall, in his 'Rural Economy of the West of England,' 1796, says, 'Intermixed with the soil, and often united with fragments of slate-rock, is found, in blocks and fragments of various sizes, a species of crystal or quartz—provincially *whittaker*—which in colour is mostly white, sometimes tinged with red or rust colour' (i. 16).

The term is in use about Ashburton, and according to Mr. Rock's 'Jim and Nell,' written in the dialect of North Devon, about Barnstaple also. It occurs in 'Halliwell,' where it is defined as 'a species of quartz,' but it is not assigned to any special locality.

Uplands is from a quarter to half a mile west of the road from Plymouth to Tavistock, and about 4 miles from the former town.

The blocks in a small plantation on the crest of the hill almost adjacent to Mr. Fox's house were perhaps the most important group I saw; for though, as I was told, a large number had been taken thence for

[1] See *Ency. Brit.*, 8th edit. 1856, xii. 88.

various purposes, the remainder contained so many specimens, and most of them of such great size, that they could not fail to rivet the attention of every geologist who saw them.

They were all partially, some of them perhaps deeply, buried in the soil, and a few were almost completely concealed by the growth of various plants rooted on them.

Of the blocks in this group, one measured $10 \times 3 \times 3{\cdot}75$ feet; and another $10{\cdot}5 \times 5{\cdot}5 \times 3$ feet, the last dimension in each case being merely the height above the surface of the soil. Making full deductions for irregularity of form, and ignoring the undoubted penetration into the ground, each of these two blocks must have contained fully 100 cubic feet; and, taking the specific gravity at 2·64, the weight of each must have been upwards of 8 tons. These were the largest blocks known anywhere in the district.

From this plantation we descended into the deep narrow valley which it overlooks on the north-west, and noted an occasional Whitaker, here and there, on the slope as we passed down, and a rather greater number in and near the stream at the bottom—about 200 feet by estimation below the level of the plantation.

On the opposite slope we again saw an occasional block, and at the summit were taken to an artificial straight gully, 60 paces in length and 25 feet in width—the length being in a direction transverse to that of the valley we had left. This gully, we were assured, had been made simply through the dislodgment of large Whitakers, which, in a long narrow stream, had lain huddled together, and, so to speak, had been quarried for road repairs.

All the Whitakers were of white opaque quartz, having, at least in some cases, a laminated structure, and traversed occasionally with veins and crystals of the same material; the crystals having in some instances a suspicious look of being pseudomorphs of feldspar.

The blocks were all more or less rugged, subangular, and without any decided traces of glacial polish or scratches. In a very few cases smooth striated surfaces presented themselves, but were probably slickensides only.

The rock of the district is the well-known Devonian shale, or ‘Shillet,’ of drab colour, having a tendency to divide into well-defined rhombohedrons; and, according to the map of the Geological Survey, this extends to great distances in all directions. It is occasionally traversed by small quartz veins, but no parent rock is known which could have supplied the Whitakers.

At least some of the blocks, instead of lying at once on the ‘Shillet,’ were lodged in a heterogeneous accumulation of clay and stones, including Whitakers from the size of an ordinary apple to some as large as a cocoa-nut.

That the blocks have travelled a considerable distance cannot be doubted; that their transportation was not effected by the action of water only, is certainly proved by their irregularity of form. From the facts I saw it seems safe to say that they occur most plentifully on high ground; and that, unless those at low levels have rolled down from above in recent times, the surface of the district must have been essentially the same at the era of transportation as it is at present.

Their presence must at times, no doubt, be an annoyance to the farmer; nevertheless, the roads, the hedges and other common walls, as

well as the large and numerous artificial rockeries in gentlemen's grounds in the district, show that they are not without value, and have been very largely utilised. Indeed, it is to be feared that, unless care be taken to prevent it, those now remaining in the spots they have so long occupied undisturbed, may become rapidly fewer, and disappear altogether at no distant date.

It must be understood that in the foregoing remarks I have confined myself to the limited district I visited. Mr. Fox told me that he had noticed them elsewhere, and especially near Maristowe, about 3 miles off as the crow flies, in a N.N.W. direction.

The Committee have confined their Report to a simple record of facts, without attempting to decide how far these facts support any special theories. It is believed that many other erratic blocks hitherto unrecorded are scattered over England, Wales, and Ireland; and that every year a large number are destroyed by agriculturists and builders. The Committee appeal, therefore, to local observers to report upon them in order that evidence so valuable with respect to many problems of the glacial epoch may be preserved.

Report of the Committee, consisting of Captain ABNEY, Professor W. G. ADAMS, *and* Professor G. CAREY FOSTER, *appointed to carry out an Investigation for the purpose of fixing a Standard of White Light. Drawn up by* Captain ABNEY (*Secretary*).[1]

SINCE the last meeting of the British Association a large number of experiments have been made with various lights, in order to ascertain the constancy of the various component radiations, the total *quantity* of such radiation having been only partially examined. Amongst others that may be mentioned are coal gas and the ordinary sperm candle. The former fails to satisfy the necessary conditions unless the burners employed are always identical, and the atmospheric pressure constant. The latter is constant when burnt at a constant barometric pressure; any alteration in the temperature of the surrounding air apparently not altering the relative intensities of the component radiations. Coal gas and candle light appear to be too yellow to use as a standard for white light, unless they be deprived of some of their lower radiations. It has been found that the 'crater' of the positive pole of the magneto-electric light emits from its central zone a light which is excessively white, and very constant in its component radiations (within limits), the size of the carbon and of the generator being immaterial. At present, testing the light from various specimens of carbons is being undertaken, and not till these experiments are more advanced can any definite idea be given as to whether this source of illumination may be taken as a possible standard. The whole question is so involved in difficulties, instrumental and optical, that it will require a longer period to propose a standard for adoption than it was at first presumed it would do. It would be well, in the face of these difficulties, to enlarge the Committee, so that more workers may be brought to expend their energies on it.

[1] This Report was not received until after the Annual Meeting, having been delayed by accident.

Report of the Anthropometric Committee, consisting of Dr. FARR, Dr. BEDDOE, Mr. BRABROOK (*Secretary*), Sir GEORGE CAMPBELL, Mr. F. P. FELLOWS, Major-General A. L. F. PITT-RIVERS, Mr. F. GALTON, Mr. J. PARK HARRISON, Mr. JAMES HEYWOOD, Mr. P. HALLETT, Professor LEONE LEVI, Dr. F. A. MAHOMED, Dr. MUIRHEAD, Sir RAWSON RAWSON, Mr. CHARLES ROBERTS, *and* Professor ROLLESTON.

[PLATES IV., V., AND VI.]

THE appointment of this Committee was renewed at the Sheffield meeting 'for the Purpose of Continuing the Collection of Observations on the Systematic Examination of Heights, Weights, &c., of Human Beings in the British Empire, and the Publication of Photographs of the Typical Races of the Empire.' Since their first appointment at the Bristol meeting, in 1875, the Committee have had the advantage of being presided over by Dr. Farr, who has taken the deepest interest in their labours, and has placed without reserve at their service his unrivalled skill and long experience in the collection and arrangement of statistics. That advantage, they regret to say, they will be deprived of in future, Dr. Farr having intimated a desire to retire from the office of Chairman on the ground of ill-health: a desire to which the Committee felt compelled to accede, while returning him their hearty thanks for his past services. Should the Committee be reappointed, Mr. F. Galton, F.R.S., has been good enough to consent to be nominated Chairman in the place of Dr. Farr.

It may be recollected that the Committee reported, in the year 1878, that their work up to that point had been rather tentative and experimental, and gave details of the forms and instruments which, after much consideration, had been adopted by them to secure both accuracy and uniformity.

The instruments are:—

1. A weighing machine.
2. A simple apparatus for measuring height.
3. A Coxeter's spirometer.
4. A spring balance for testing strength of arm.

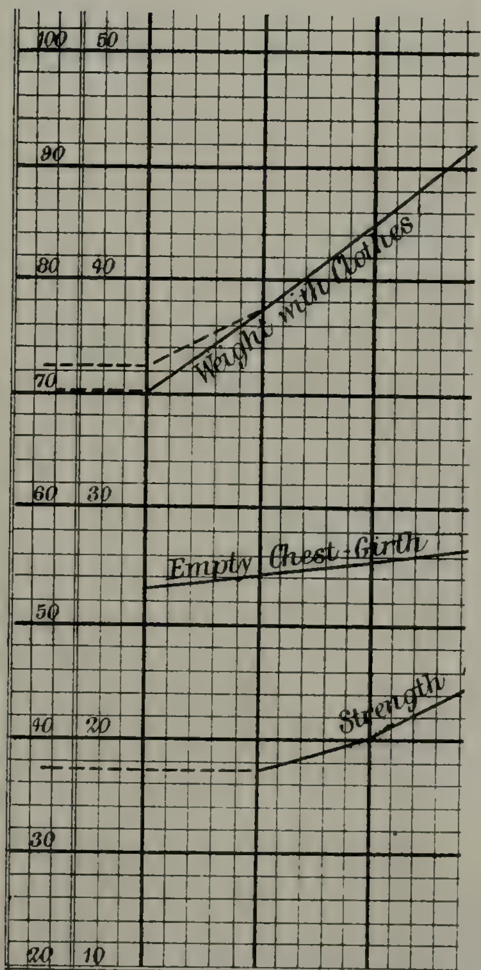
In the Report of last year they were able to state that they had collected 12,000 original observations on weight and height, supplemented in many cases by observations of chest-girth, colour of hair and eyes, strength, and eyesight, and to furnish a number of tables, based on selected portions of these returns, indicating the results to be obtained from them. In the present year they have the satisfaction of reporting a considerable addition to the materials at their command, the new observations of the year being nearly equal in number to all those collected in previous years. These are shown in Tables I. and II.

The Committee submit that they are carrying on a work of no mean value to social statistics, supplementary to that of the National Census; one that could not be performed except through voluntary association, such as they are exerting themselves successfully to obtain.

They feel it a duty to return hearty thanks to the numerous observers, whose names are mentioned in these tables (I. and II.), and who have rendered their zealous and obliging services at great sacrifice of time. They have also to thank the Registrar-General, and Mr. W. Clode and Mr. J. T. Hammick, of the General Register Office, for courteous and kind assistance.

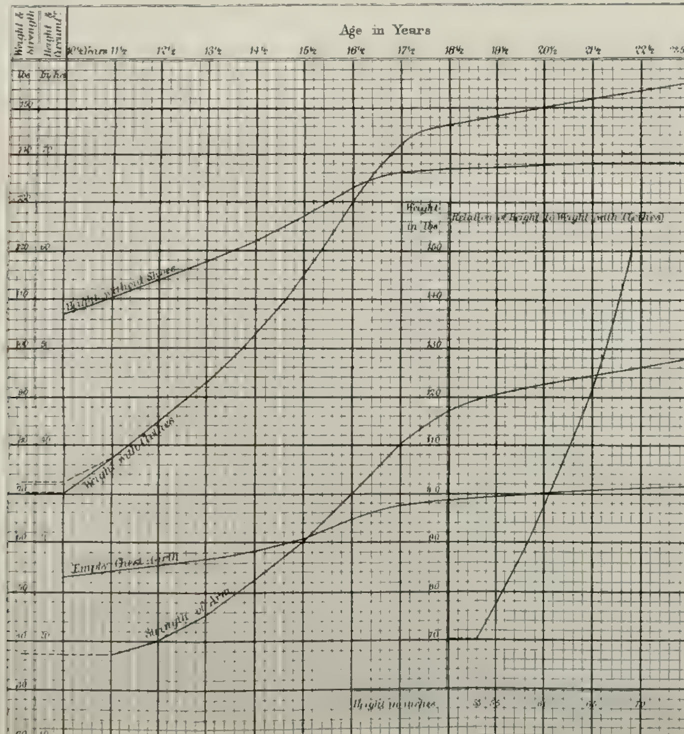
Diagram N°III.

Tracings of the Annual Growth in height of 13 Girls



C. Roberts.

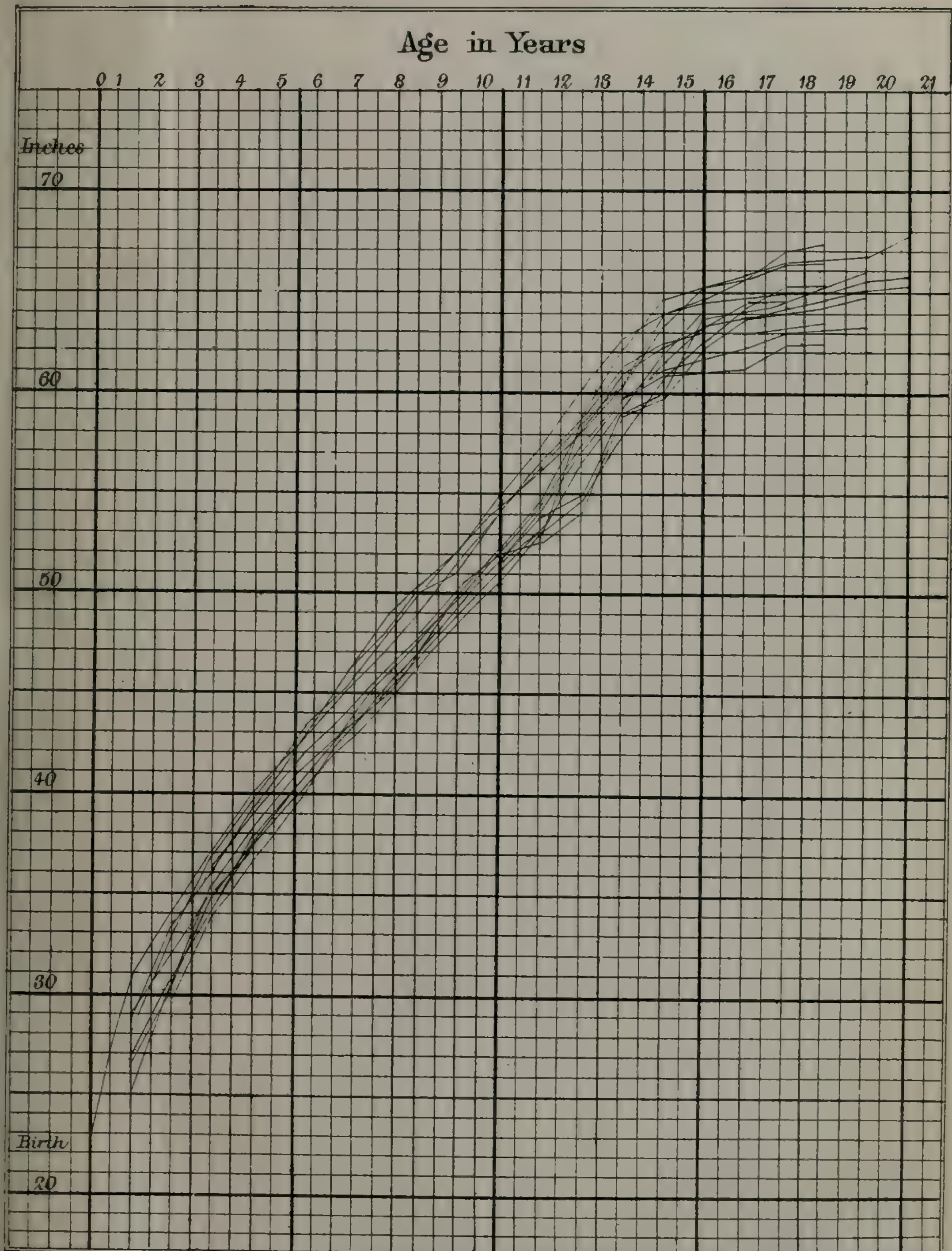
Diagram No. 1 *Chart showing the mean Heights, Chest-girths, Weights, and Strength of Class I (Standard) given in Tables from V to X and the relation of the Weight to the Height*



Illustrating the Report of the Anthropometric Committee

Diagram No. III.

Tracings of the Annual Growth in height of 13 Girls



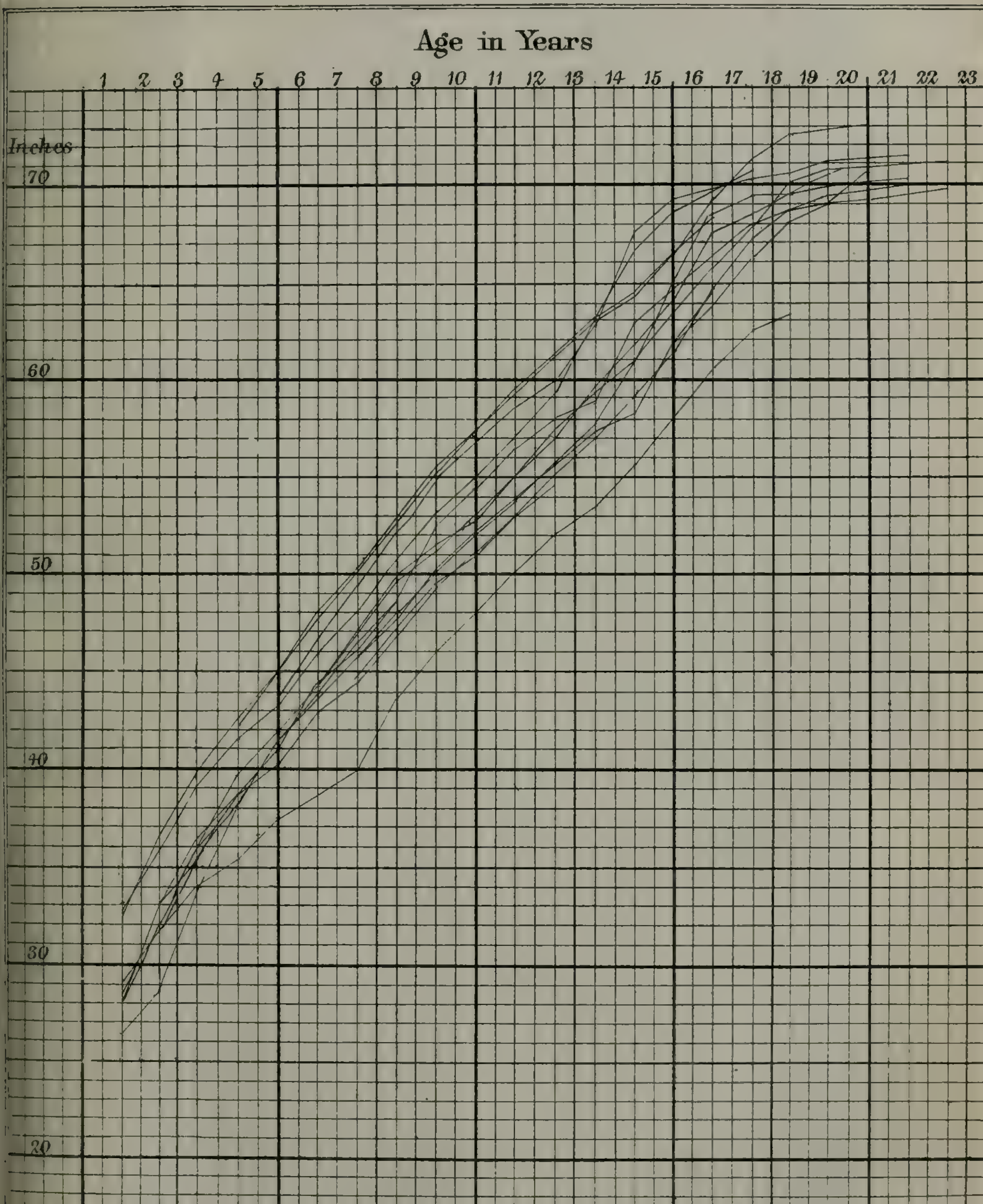
C Roberts

Spottiswoode & Co. Lith. London

Illustrating the Report of the Anthropometric Committee

Diagram No. 11.

Tracings of the Annual Growth in height of 12 Boys



C Roberts

Spottiswoode & Co. Lith. London

Illustrating the Report of the Anthropometric Committee

I. *As to Classification of Returns.*

In deciding upon the arrangement for practical purposes of returns so various in their origin, and yet consisting in so large a proportion of information derived from special sources, the first consideration has been to establish a classification of the returns. In this the Committee have had material assistance from their colleague, Mr. Roberts, who has prepared the subjoined scheme of classification (Table III.), which the Committee have adopted. It is based on the principle of collecting into a standard class as large a number of cases as possible which imply the most favourable conditions of existence in respect to fresh air, exercise, and wholesome and sufficient food—in one word, nurture—and specialising into classes which may be compared with this standard, those which depart more or less from the most favourable condition. By this means, in respect to social condition, the influence of mental and manual work; in respect to nurture, the influence of food, clothing, &c., on development; in respect to occupation, the influence of physical conditions; and in respect to climate and sanitary conditions, the influence of town and country life may, as sufficient materials accumulate under the hands of observers, be determined.

The classification has been constructed on the physiological and hygienic laws which are familiar to the students of sanitary science, and on a careful comparison of the measurements of different classes of the people, and especially of school children of the age of from eleven to twelve years. This age has been selected by Mr. Roberts as particularly suited to the study of the *media*, or conditions of life, which influence the development of the human body, as it is subject to all the wide and more powerful agencies which surround and divide class from class, but is yet free from the disturbing elements of puberty and the numerous minor modifying influences, such as occupation, personal habits, &c., which in a measure shape the physique of the adult. Table IV. contains some of the data on which the classification has been based. The most obvious fact which it discloses, apart from the check which growth receives as we descend lower and lower in the social scale, is, that a difference of five inches exists between the average statures of the best and the worst nurtured classes of the community. When it is remembered that at birth children are of the same average size in all classes, it is evident that the conditions of life, combined with heredity, exert a most potent influence on the physique of the population of this country, and it will be seen that the labours of the Committee are directed to the elucidation of a subject which is of great national importance as well as of scientific interest.

II. *Results of Returns relating to Class I. (Standard No. I.)*

Tables V.–X.[1] and the accompanying diagram give the results of the returns which the Committee have obtained relating to individuals coming under the Standard Class (Class I.)

[1] It is necessary to call attention to the difference in the meaning of the terms *average* and *mean*—which in common language are synonymous—when used in this report. An *average* is obtained by dividing the sum of the values observed by the number of observations, while a *mean* is the value at which the largest number of observations occur. An *average* includes and is influenced by exceptional cases, while a *mean* excludes exceptional cases, and is consequently uninfluenced by them.

TABLE I.—List of Observations furnished up to the end of the year 1879.

Sources of Information	By whom Furnished	Number of Observations (Males)					
		Birth-place, Origin, and Sex	Age, Height, and Weight	Colour of Hair and Eyes	Girth of Chest	Strength of Arm	Eyesight
1. Cadets Royal Military College, Sandhurst	General Napier and Col. F. Middleton	300	300	300	300	300	300
2. Boys at Westminster School	Dr. Scott	200	200	200	—	200	—
3. Students at Aberystwith	Professor Rudler	40	40	40	40	40	40
4. Boys at Christ's Hospital	Major Brackenbury	—	1936	—	846	—	—
5. Medical Students	Dr. Norman Chevers	46	46	46	46	46	41
6. Felstead Grammar School	Mr. E. Shedd, M.R.C.S.	62	62	62	62	62	—
7. Men in Mr. Whiteley's employment	Mr. Whiteley	242	242	—	—	242	—
8. Letter Sorters	Dr. Waller Lewis	—	1980	—	1180	—	—
9. Metropolitan Police	Lieut.-Col. Sir E. W. Henderson	205	205	205	205	205	205
10. City Police (first instalment)	Col. Fraser	60	60	60	60	60	60
11. Metropolitan Fire Brigade	Capt. Shaw	80	80	80	80	80	80
12. Jews	Drs. Davis and Eskell	140	140	140	140	—	—
13. „ (another source)		20	20	20	20	—	—
14. Industrial and other Classes	Drs. Bain and Massey	82	82	42	42	—	6
15. Workmen of Messrs. Howard	Messrs. Howard	67	67	66	65	62	19
16. Workmen, &c.	Dr. Bain	28	28	28	28	28	—
17. Scotland, various occupations	Mr. J. Whitney	20	20	20	20	—	—
18. Weavers, Holmfirth	Dr. Morehouse	120	120	—	120	120	—
Rifle Volunteers.							
19. Northumberland	Capt. Clark and Sergt. Treble	200	200	200	200	—	—
20. Cumberland	Dr. Syme	40	40	40	40	—	—
21. Cornwall	Capts. Smith, Sharp, and Williams	110	110	110	110	—	—

22. Somerset	Drs. Hunt and Kemmins	155	155	155	155	—	—
23. Essex	Capt. Humphreys and Mr. Shedd	89	89	89	89	13	14
24. Suffolk	Major Crowfoot	135	135	135	135	—	—
25. Kent	Capt. Brown	90	90		—	90	—
26. Royal Surrey Militia	General Lane Fox	459	459	459	459	459	459
27. Volunteers and Militia, Surrey	Ditto	124	124	124	124	124	124
28. Recruits	Inspector-General Lawson, Dr. Skipton, and Dr. Fraser	100	100	100	100	—	—
29. ,,		32	32	—	32	—	—
30. ,,		79	79	62	79	—	—
31. ,,		190	190	—	190	—	—
32. ,,		100	100	—	100	—	—
33. ,,		218	218	88	218	—	—
34. ,,		128	128	108	128	—	20
35. ,,		260	356	—	96	—	—
36. ,,		200	200	200	200	—	—
37. ,,		199	199	199	199	—	—
38. Soldiers		20	20	20	20	—	—
39. H.M.S. *Fisguard*	Dr. Fisher	59	59	59	59	—	—
Industrial Schools.							
40. Newcastle	Mr. R. Willoughby	150	150	150	150	—	—
41. Birmingham	Mr. C. F. Vinall	84	84	84	84	—	—
42. Greenock	Mr. Alexander Thomson	100	100	100	100	—	—
43. Park Row (Bristol)	Dr. Beddoe	70	70	70	—	—	—
44. St. James (Bristol)		70	70	70	—	—	—
45. Sale, near Manchester (Girls)	Miss Pettit	80	80	80	—	—	—
46. Criminals	Mr. Francis Galton, F.R.S.	—	2480	—	—	—	—
		5254	11745	4011	6321	2131	1368

To these are to be added the very extensive observations (50,000 individuals) collected by Mr. Charles Roberts.

TABLE II.—List of Observations received during the present Year (1880).

Sources of Information	By whom Furnished	Number of Observations (Males)					
		Birth-place, Origin, and Sex	Age, Height, and Weight	Colour of Hair and Eyes	Girth of Chest	Strength of Arm	Eyesight
1. Oxford Undergraduates	Mr. H. Symonds, M.R.C.S.	17	17	17	17	17	—
2. Marlborough College	The Rev. T. A. Preston	—	1900	—	1900	460	—
3. Radley School	The Warden	20	20	20	20	—	20
4. Uppingham School	Mr. Besiégel	300	300	300	300	—	—
5. Blind School for Gentlemen, Worcester	Mr. S. Forster	30	30	30	30	30	—
6. Bristol, Upper Middle Class	Dr. Beddoe	40	40	40	—	—	—
7. City Police (2nd instalment)	Col. Fraser	140	140	140	140	140	140
8. Telegraph Messengers, &c.	Mr. Steet, F.R.C.S.	—	4412	—	—	—	—
9. Candidates for Civil Service Appointments, Warders, &c.	Dr. Power, H.M. Convict Prison, Portsmouth	—	660	660	660	—	—
10. Printers	Messrs. Spottiswoode & Co.	45	45	—	45	45	—
Rifle Volunteers.							
11. Cornwall	Captain Baker and Drs. Rean and Thompson	85	85	85	85	20	—
12. Cumberland	Dr. Wotherspoon	51	51	51	51	51	—
13. Devonshire	Dr. Rouse	45	45	45	45	45	45
14. Kent	Capt. Drury	10	10	10	10	10	—

15.	Essex	Mr. E. Shedd, M.R.C.S.	—	70	70	70	20	—
16.	Lancashire	Capt. Woodcock and Mr. Shaughnessy	154	154	154	154	54	—
17.	Norfolk	Capt. Forester	65	65	65	65	—	65
18.	Oxford	Mr. Hussey	—	100	—	100	—	—
19.	Northumberland	Capt. Clark, Lieut. Clark, and Mr. A. Carter	63	63	63	63	40	40
20.	Somerset	Capts. Moger and Bennett, Dr. Fowler, and Lieut. Robinson	226	226	226	226	163	172
21.	Westmoreland	Capt. Harrison	67	67	67	67	—	—
22.	Flintshire	Capt. Frost and Mr. Leggatt	87	87	87	87	—	87
23.	Glamorganshire	Drs. Evan Jones and D. Davies.	191	191	191	191	91	191
24.	Recruits	Inspector-General Lawson and Mr. Myers, M.R.C.S. (Coldstream Guards	590	590	590	590	200	200
25.	Soldiers	Inspector-General Lawson	—	358	—	—	—	—
	Training Ships.							
26.	H.M.S. *Britannia* (Cadets)	Mr. W. Telfer, L.R.C.S.	—	150	—	150	—	—
27.	H.M.S. *Ganges*	Mr. P. Keelan, L.R.C.S.	40	40	40	40	—	—
28.	H.M.S. *Implacable*	Dr. Campbell	380	380	—	360	—	—
29.	H.M.S. *Impregnable*	Mr. Hadlow, M.R.C.S.	260	260	260	—	—	—
30.	Industrial School, Swinton, near Manchester	Mr. R. Sutton	300	300	300	300	300	300
31.	Criminals	Dr. Beddoe	—	1100	—	—	—	—
			3206	11956	3511	5766	1686	1260

Some further observations have also been placed at the disposal of the Committee by Dr. Beddoe, which have not yet been enumerated.

TABLE III.—Classification of the British Population according to *Media*, or the conditions of life.

*Social Condition.**—Non-labouring Classes			Labouring Classes.			
Nurture.†—Very Good		Good	Imperfect		Bad	
Professional Classes ‡ (Upper and Upper Middle Classes) 4·46 per cent.		Commercial Class (Lower Mid. Classes) 10·30 per cent.	Labourers 47·46 per cent.	Artisans 26·82 per cent.	Industrial Classes (Sedentary Trades) 10·90 per cent.	Selected Classes
Out-door Country §	In-door Towns	In-door Towns	Out-door Country	In-door Towns	In-door Towns	
CLASS I. Country-gentlemen. Gentlemen-farmers. Officers of Army and Navy.	Auxiliary Forces. Clergymen. Lawyers. Doctors. Civil Engineers. Architects. Dentists. Civil Servants. Authors. Artists. Teachers. Musicians. Actors. Bankers. Merchants (Wholesale).	CLASS II. Teachers in Elementary Schools. Clerks. Shopkeepers. Shopmen. Dealers in „ Drugs. „ Books. „ Wool. „ Silk. „ Cotton. „ Foods. „ Drinks. „ Furniture. „ Metals. „ Glass. „ Earthenware. „ Fuel, &c.	CLASS III. Labourers and Workers on Agriculture. „ Gardens. „ Roads. „ Railways. „ Quarries. Navvies. Porters. Guards. Woodmen. Brickmakers. Labourers, &c., on Water. „ Sailors. „ Fishermen. „ Watermen. Labourers, &c., in Mines. „ Coal. „ Minerals.	CLASS IV. Workers in „ Wood. „ Metal. „ Stone. „ Leather. „ Paper. &c. Engravers. Photographers. Printers. &c.	CLASS V. Factory Operatives. Tailors. Shoemakers. &c.	CLASS VI. Policemen. Fire Brigade. Soldiers. Recruits. Messengers? Industrial-Schools. Criminals. Idiots Lunatics.

* Social Condition; (influences of leisure, mental and manual labour).
† Nurture; (influences of food, clothing, nursing, domestic surroundings, &c.)
‡ Occupation; (influences of external physical conditions, exercise, &c.) Percentage of male population, including male children (Census of 1871).
§ Climatic and sanitary surroundings.

TABLE IV.—Table showing the Relative Statures of Boys of the age of 11 to 12 years, under different social and physical conditions of life. The zig-zag line running through the means shows the degradation of stature as the boys are further and further removed from the most favourable conditions of growth. (C. Roberts.)

Height in inches	Total No. of Obs.	Public Schools — Country	Public Schools — Towns	Middle-class Schools — Upper — Towns	Middle-class Schools — Lower — Towns	Elementary Schools — Agricultrl. Labourers — Country	Elementary Schools — Artisans — Towns	Elementary Schools — Factories and Work-shops — Country	Elementary Schools — Factories and Work-shops — Towns	Military Asylums	Pauper Schools ?	Industrial Schools	Total per-centages
60 to 61	6	2 1			3 1		1						2
59–	16	2 1		3 1	5 1	2 1	2 1			1			5
58–	35	9 6		9 3	8 2	5 1	0 1	2 1		2			15
57–	66	11 8		17 6	13 4	4 2	4 2	5 1	5 1	7 1		1 1	25
56–	118	21 14		23 8	27 7	14 4	4 2	10 3	3 1	15 2			42
55–	230	28 19		35 12	57 14	32 10	15 8	13 6	17 5	33 4			78
54–	329	33 22		53 18	68 17	47 16	24 13	36 12	20 6	46 6		2 3	113
53–	361	15 10		55 19	58—15	47 16	26 15	34 13	38 11	84 10		4 6	115
52–	441	14 9		37 12	61 15	58 19	36—20	52 17	59 17	118 14		6 9	132
51–	370	6 5		25 9	40 10	36 12	28 15	45 16	57—17	123 14		10 15	113
50–	367	7 4		23 7	27 7	32 10	17 10	46 15	61 18	143 17		11 18	106
49–	252	2 1		8 3	20 5	14 5	12 6	31 10	40 12	114 14		11 18	74
48–	132			3 1	1 1	7 2	4 3	11 4	20 6	76 9		10 15	41
47–	102			3 1	4 1	5 1	7 3	5 1	13 3	59 7		6 9	28
46–	22					1 1	1 1	3 1	7 2	7 1		3 4	10
45–	12								1 1	10 1		1 1	3
44–	1									0		1 1	1
43–	1									1			
42 to 43	1									1			
Total	2862	150 100		294 100	392 100	304 100	181 100	293 100	341 100	840 100		66 100	90
Average height	52·60	54·98		53·85	53·70	53·01	52·60	52·17	51·56	51·20		50·02	
Mean height	52·5	55·0	54 5	54·0	53·5	53·0	52·5	52·0	51·5	51·0	50·5	50·0	

CLASS I. (Standard). TABLE V.—Showing the actual, average, and mean HEIGHT of 10,651 Boys and Men between the Ages of 10 and 50 Years.

Height in inches	Age last Birthday														Centi-mètres.
	10 years	11–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23 to 50	
77–78	—	—	—	—	—	—	—	—	1	1	—	—	—	—	195·5
76–	—	—	—	—	—	—	—	2	2	—	2	1	1	—	193·0
75–	—	—	—	—	—	1	—	4	3	1	3	3	1	1	190·5
74–	—	—	—	—	—	—	2	2	7	9	5	2	2	2	187·9
73–	—	—	—	—	—	—	—	10	30	21	12	13	6	10	185·4
72–	—	—	—	—	1	2	19	49	58	48	37	18	12	11	182·8
71–	—	—	—	1	—	4	16	124	121	72	42	31	27	27	180·3
70–	—	—	1	—	—	10	50	181	214	104	61	58	31	44	177·8
69–	—	—	—	—	8	25	83	227	238	158	82	49	40	47	175·2
68–	—	—	—	2	10	33	129	292	283	169	71	56	45	44	172·7
67–	—	1	—	4	20	77	176	277	250	129	49	52	34	41	170·1
66–	—	—	—	6	45	85	136	263	216	101	41	48	28	32	167·6
65–	—	—	—	10	55	95	149	173	117	65	31	21	19	15	165·1
64–	—	—	1	17	57	130	134	118	94	40	17	8	10	14	162·5
63–	—	—	5	35	95	108	68	78	63	19	6	3	6	2	160·0
62–	—	1	9	50	103	108	56	31	14	9	1	1	1	—	157·4
61–	—	1	19	76	110	86	31	11	8	4	—	—	—	2	154·9
60–	—	6	37	112	120	80	19	6	3	1	—	—	—	—	152·4
59–	—	3	45	124	107	46	18	1	2	—	—	—	—	—	149·8
58–	—	14	62	124	95	36	6	1	—	—	1	—	—	—	147·3
57–	4	30	76	109	61	25	6	1	—	—	—	—	—	—	144·7
56–	7	27	79	77	23	12	2	1	—	—	—	—	—	—	142·2
55–	16	46	80	59	25	4	—	—	—	—	—	—	—	—	139·7
54–	16	47	36	37	18	4	1	—	—	—	—	—	—	—	137·1
53–	23	25	19	15	4	1	1	—	—	—	—	—	—	—	134·6
52–	17	18	16	6	4	1	—	—	—	—	—	—	—	—	132·0
51–	11	11	2	2	4	—	—	—	—	—	—	—	—	—	129·5
50–	3	7	1	2	1	—	—	—	—	—	—	—	—	—	127·0
49–	2	4	1	1	—	1	—	—	—	—	—	—	—	—	124·4
From 48 to 49	2	1	1	—	—	—	—	—	—	—	—	—	—	—	121·9
Total . . .	101	242	490	869	966	974	1102	1852	1724	951	461	361	263	292	—
Mean Height.	53·5	55·0	57·0	59·0	61·0	63·5	66·5	68·0	68·5	68·75	69·0	69·0	69·0	69·0	—
Average Height	53·69	55·23	57·29	59·08	61·29	63·61	66·23	67·81	68·26	68·58	69·08	68·70	68·75	68·84	—

NOTE.—This Table contains statistics derived from the following sources:—*Public Schools*—Clifton, Eton, Felstead, Haileybury, Marlborough, Magdalen, Radley, Wellington, Westminster, and Uppingham. *Military and Naval Colleges*—Britannia, Sandhurst, and Woolwich; the Universities of Oxford and Cambridge and Medical Schools, and the professional classes included in the returns from all other sources.

CLASS I. (Standard). TABLE VI.—Showing the actual, average, and mean WEIGHT (including Clothes) of 9090 Boys and Men between the Ages of 10 and 50 Years.

Weight in lbs.	Age last Birthday														Kilo-grammes
	10 years	11–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23 to 50	
259	—	—	—	—	—	—	—	—	—	—	—	—	—	—	117·58
245–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	111·23
231–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	104·87
217–	—	—	—	—	—	—	—	—	—	—	—	—	—	3	98·51
203–	—	—	—	—	—	—	—	—	4	2	—	2	—	—	92·16
189–	—	—	—	—	—	—	—	8	12	6	2	4	2	5	85·80
175–	—	—	—	—	—	1	4	23	48	34	30	17	10	23	79·45
168–	—	—	—	—	—	1	5	48	69	56	25	29	15	22	76·27
165–	—	—	—	—	—	1	5	30	42	24	20	16	13	8	74·91
160–	—	—	—	—	1	4	12	88	119	70	48	41	24	35	72·64
155–	—	—	—	—	1	2	19	125	143	83	58	46	36	25	70·37
150–	—	—	—	—	—	5	31	155	193	122	65	53	27	40	68·10
145–	—	—	—	—	2	12	64	215	221	132	65	44	20	27	65·83
140–	—	—	—	1	4	18	89	211	226	131	57	35	25	34	63·56
135–	—	—	—	—	10	38	79	221	194	118	36	30	20	16	61·29
130–	—	—	—	1	17	41	110	189	124	84	17	29	12	13	59·02
125–	—	—	—	7	30	62	98	167	118	40	19	11	4	13	56·75
120–	—	—	—	5	42	58	93	102	68	21	6	6	4	3	54·48
115–	—	—	2	12	39	67	77	65	33	11	2	2	3	6	52·21
110–	—	—	1	20	70	66	44	26	20	3	—	—	—	1	49·94
105–	—	—	9	29	65	69	36	17	2	3	—	—	—	—	47·67
100–	—	3	17	64	85	65	30	7	1	—	—	—	—	—	45·40
95–	—	7	29	86	119	47	18	4	—	—	—	—	—	—	43·13
90–	1	8	49	95	106	47	9	3	—	—	1	—	—	—	40·86
85–	2	20	62	108	83	22	6	—	1	—	—	—	—	—	38·59
80–	14	36	81	93	29	14	2	—	—	—	—	—	—	—	36·32
75–	23	47	66	57	33	6	3	—	—	—	—	—	—	—	34·05
70–	30	42	31	31	9	6	—	—	—	—	—	—	—	—	31·78
65–	12	13	15	8	1	—	—	—	—	—	—	—	—	—	29·51
60–	8	6	6	3	2	—	—	—	—	—	—	—	—	—	27·24
From 55 to 60	2	3	1	1	—	—	—	—	—	—	—	—	—	—	24·97
Total . . .	92	185	369	621	748	652	834	1705	1638	940	451	365	215	275	—
Mean Weight.	72·5	77·5	85·0	92·5	102·5	115·0	130·0	142·5	145·0	147·5	150·0	152·5	155·0	155·0	—
Average Weight	73·97	78·72	84·91	91·57	102·15	114·32	129·48	141·66	146·44	148·46	152·36	152·72	152·75	154·59	—

NOTE.—This table contains statistics derived from the following sources:—*Public Schools*—Eton, Felstead, Marlborough, Magdalen, Radley, Wellington, Westminster, Uppingham; *Military and Naval Colleges*—Britannia, Sandhurst, Woolwich, Midshipmen; the Universities of Oxford and Cambridge and Medical Schools, and the Professional Classes included in the returns from all other sources.

CLASS I. (Standard). TABLE VII.—Showing the actual, average, and mean CHEST-GIRTH of 8566 Boys and Men between the Ages of 10 and 50 Years.

Chest-girth in Inches.	Age last Birthday														Centi-mètres
	10 Years	11–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23–50	
44–45	—	—	—	—	—	—	—	—	—	—	—	—	—	2	111·7
43–	—	—	—	—	—	—	—	—	—	—	—	—	—	—	109·2
42–	—	—	—	—	—	—	—	—	—	—	—	1	—	3	106·6
41–	—	—	—	—	—	—	—	—	1	2	1	—	—	3	104·1
40–	—	—	—	—	—	—	—	2	2	6	7	4	1	5	101·6
39–	—	—	—	—	—	—	—	9	18	8	8	4	9	13	99·0
38–	—	—	—	—	—	—	7	30	45	28	15	18	12	19	96·5
37–	—	—	—	—	2	—	11	66	98	41	48	36	24	27	93·9
36–	—	—	—	—	—	2	24	151	147	96	69	72	37	43	91·4
35–	—	—	—	—	2	9	33	213	245	168	85	69	33	53	88·9
34–	—	—	—	1	5	13	88	315	338	227	106	72	54	37	86·3
33–	—	—	—	1	8	37	140	347	310	175	69	46	31	33	83·8
32–	—	—	—	2	14	52	146	318	229	123	34	34	18	18	81·2
31–	—	1	1	21	57	104	120	177	127	58	16	11	7	8	78·7
30–	—	2	6	48	89	115	101	78	46	13	3	3	2	4	76·2
29–	—	10	36	82	135	94	47	25	9	4	2	—	—	—	73·6
28–	6	18	57	135	115	86	37	12	—	—	1	—	—	—	71·1
27–	3	23	92	143	81	47	11	6	1	—	—	—	—	—	68·5
26–	11	28	64	79	43	20	7	—	1	—	—	—	—	—	66·0
25–	5	14	34	30	16	6	2	—	—	—	—	—	—	—	63·5
24–	2	2	3	12	6	1	—	1	—	—	—	—	—	—	60·9
23–	—	1	3	3	1	1	1	—	1	—	—	—	—	—	58·4
22–	—	—	—	—	1	—	—	—	—	—	—	—	—	—	55·8
From 21 to 22	1	1	1	—	—	—	—	—	—	—	—	—	—	—	53·3
Total	28	100	297	557	575	587	775	1750	1618	949	464	370	228	268	—
Mean Chest-girth	26·5	27·0	27·5	28·0	29·0	30·25	32·25	33·5	34·25	34·5	35·0	35·25	35·5	35·75	—
Average Chest-girth	26·54	27·26	27·47	28·15	29·18	30·33	32·34	33·82	34·33	34·52	35·15	35·27	35·30	35·79	—

NOTE.—This table contains statistics derived from the following sources:—*Public Schools*—Eton, Felstead, Marlborough, Magdalen, Radley, Wellington, Westminster, Uppingham; *Military and Naval Colleges*—Britannia, Midshipmen, Sandhurst, Woolwich; the Universities of Oxford and Cambridge and Medical Schools and the Professional Classes, included in the returns from all other sources.

Class I. (Standard). Table VIII.—Showing the actual, average, and mean Strength of 1098 Boys and Men between the Ages of 10 and 50 Years.

Strength, Drawing Power of Arm in Lbs.	Age last Birthday. 10 years	11–	12–	13–	14–	15–	16–	17–	18–	19–	20–	21–	22–	23 and under 50	Kilo-grammes
190	—	—	—	—	—	—	—	—	1*	—	—	—	—	—	—
160–	—	—	—	—	—	—	—	1*	—	—	—	1	—	—	72·64
155–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	70·37
150–	—	—	—	—	—	—	—	—	—	—	—	—	—	1	68·10
145–	—	—	—	—	—	—	—	—	—	1	—	—	—	1	65·83
140–	—	—	—	—	—	—	—	1	—	1	—	—	—	2	63·56
135–	—	—	—	—	—	—	—	1	2	1	—	—	—	—	61·29
130–	—	—	—	—	—	—	—	—	1	1	—	—	—	—	59·02
125–	—	—	—	—	—	1	—	1	1	—	—	1	—	—	56·75
120–	—	—	—	—	—	1	1	2	1	5	4	—	—	3	54·48
115–	—	—	—	—	—	—	—	1	4	1	2	—	1	2	52·21
110–	—	—	—	—	—	—	—	3	3	4	3	—	2	2	49·94
105–	—	—	—	—	1	—	4	3	6	11	5	—	1	4	47·67
100–	—	—	—	—	1	2	3	—	13	5	—	1	1	9	45·40
95–	—	—	—	—	1	1	1	8	8	9	7	3	4	5	43·13
90–	—	—	—	—	1	2	4	7	7	8	6	1	2	7	40·86
85–	—	—	—	—	1	1	7	7	13	15	7	2	2	1	38·59
80–	—	—	—	1	1	5	5	8	20	18	5	1	1	9	36·32
75–	—	—	—	1	3	11	10	14	17	10	5	3	3	3	34·05
70–	—	—	—	—	7	17	22	13	17	5	3	2	2	7	31·78
65–	—	—	—	2	6	8	20	9	8	10	2	3	—	1	29·51
60–	—	—	—	3	21	20	13	8	7	4	—	1	—	—	27·24
55–	—	—	—	5	11	26	14	8	1	2	—	—	—	1	24·97
50–	—	1	3	13	38	23	5	3	—	1	—	—	—	—	22·70
45–	1	3	4	13	32	20	11	—	—	—	—	—	—	—	20·43
40–	—	5	11	26	34	14	3	—	—	—	—	—	—	—	18·16
35–	—	7	8	18	13	7	2	—	—	—	—	—	—	—	15·89
30–	1	5	11	7	2	—	—	—	—	—	—	—	—	—	13·62
From 25 to 30	—	4	1	—	1	—	—	—	—	—	—	—	—	—	11·35
Total . . .	2	25	38	89	174	159	125	98	130	112	49	19	19	59	—
Mean Strength	—	37·5	40·0	45·0	50·0	60·0	70·0	80·0	87·5	90·0	92·5	—	95·0	97·5	—
Average Strength	—	37·70	39·47	45·81	52·87	60·51	69·42	80·44	86·48	90·00	93·93	88·29	92·76	97·49	—

Note.—This table includes statistics derived from the following sources:—*Public Schools*—Felstead, Marlborough, Westminster; Sandhurst College and Medical Schools; and the Professional Classes included in the general returns from all other sources. * Not included in the average.

CLASS I. (Standard). TABLE IX.—Showing the average Height, Weight, Chest-girth, and Strength of Arm, and their relation to each other.

Age last Birthday	Averages				Ratios of average height, weight, chest-girth, and strength						Average annual increase				Ratios of average annual increase of height, weight, chest-girth, and strength					
	Height in inches	Weight in lbs. including clothes	Chest-girth in inches	Strength of arm in lbs.	Pounds of weight to one inch of height	Pounds of weight to one inch of chest-girth	Inches of chest-girth to one inch of height	Pounds of strength to one inch of height	Pounds of strength to one inch of chest-girth	Pounds of strength to one pound of weight	Height in inches	Weight in lbs.	Chest-girth in inches	Strength of arm in lbs.	Pounds of weight to one inch of height	Pounds of weight to one inch of chest-girth	Inches of chest-girth to one inch of height	Pounds of strength to one inch of height	Pounds of strength to one inch of chest-girth	Pounds of strength to one pound of weight
10 years	53·69	73·97	26·54	—	1·38	2·03	·494	—	—	—	—	—	—	—	—	—	—	—	—	—
11–	55·23	78·72	27·26	37·70	1·42	2·89	·493	·68	1·38	·48	1·54	4·75	·72	—	3·08	6·60	·468	—	—	—
12–	57·29	84·91	27·47	39·47	1·48	3·09	·479	·69	1·44	·46	2·06	6·19	·21	1·77	3·00	29·48	·102	·86	8·43	·29
13–	59·08	91·57	28·15	45·81	1·55	3·25	·476	·78	1·63	·50	1·79	6·66	·68	6·34	3·72	9·79	·380	3·54	9·32	·95
14–	61·29	102·15	29·18	52·87	1·67	3·50	·476	·86	1·81	·52	2·21	10·58	1·03	7·06	4·79	10·27	·466	3·19	6·85	·67
15–	63·61	114·32	30·33	60·51	1·79	3·77	·477	·95	2·00	·53	2·32	12·17	1·15	7·64	5·24	10·58	·496	3·29	6·64	·63
16–	66·23	129·48	32·34	69·42	1·95	4·00	·488	1·05	2·15	·54	2·62	15·16	2·01	8·91	5·79	7·54	·767	3·40	4·43	·59
17–	67·81	141·66	33·82	80·44	2·09	4·31	·499	1·19	2·37	·57	1·58	12·18	1·48	11·02	7·71	8·23	·937	6·97	7·45	·91
18–	68·26	146·44	34·33	86·48	2·15	4·27	·503	1·27	2·52	·59	0·45	4·78	0·51	6·04	10·62	9·37	1·133	13·42	11·84	1·26
19–	68·58	148·46	34·52	90·00	2·16	4·30	·503	1·31	2·61	·61	0·32	2·02	0·19	2·01	6·31	10·63	·594	6·38	10·74	1·01
20–	69·08	152·36	35·15	93·93	2·20	4·33	·509	1·36	2·67	·62	0·50	3·90	0·63	3·93	7·80	6·19	1·260	7·86	6·24	1·01
21–	68·70	152·72	35·27	88·29	2·22	4·33	·513	1·29	2·50	·58	—	0·36	0·12	—	—	3·00	—	—	—	—
22–	68·75	152·75	35·30	92·76	2·22	4·33	·513	1·35	2·63	·61	0·05	0·03	0·03	4·47	·60	1·00	0·600	89·40	149·00	149·00
23–50	68·84	154·59	35·79	97·49	2·25	4·32	·520	1·42	2·72	·63	0·09	1·84	0·49	4·73	20·44	3·76	5·444	52·55	9·65	2·57

CLASS I. (Standard). TABLE X.—Showing the Mean Growth.

Age	Percentage Actual Growth				Percentage Relative Growth (Difference compared with previous year)			
	Height	Weight	Chest-girth	Strength	Height	Weight	Chest-girth	Strength
At 11	2·8	6·9	1·8	—	—	—	—	—
12	3·6	9·7	1·8	6·6	+28·5	+40·6	—	—
13	3·5	8·8	1·8	12·5	− 2·7	− 9·3	—	+ 89·4
14	3·4	10·8	3·6	11·1	− 2·8	+22·7	+100·	− 11·2
15	4·1	12·2	4·3	20·	+20·6	+12·9	+ 19·4	+ 80·
16	4·7	13·	6·5	16·6	+14·6	+ 6·5	+ 51·1	− 17·1
17	2·2	9·6	3·8	14·3	−53·2	−26·1	− 41·5	+ 19·1
18	·7	1·7	2·2	9·3	−68·2	−82·0	− 40·5	− 34·9
19	·3	1·7	·7	2·8	−57·1	—	− 68·1	− 70·
20	·3	1·7	·7	2·7	—	—	—	− 3·5
21	·0	1·6	·7	2·7	—	5·8	—	0·
22	·0		·7					
23–50	·0	1·9	·7	2·6	—	+18·7	—	− 3·7

The first part of this table (X.) shows the actual percentage growth in each year under each of the four heads. The second part shows the percentage growth of each year, compared with its immediate predecessor, and thus indicates how far the changes under the several heads are similar and contemporaneous, or otherwise.

It will be seen in the first part that there is a constant, but more or less uneven, growth under each head throughout the whole period, increasing annually up to 16 or 17, and then rapidly diminishing.

The data at 10 are not sufficiently reliable for purposes of comparison, because they represent selected boys, who were nearly 11 years old; and those above 20 are imperfect in both numbers and variety. For the first reason it may not be safe to compare the percentage growth at 12 with that at 11, which depends upon the data at 10. On the remainder of the table the following observations may be made :

Between 11 and 14 the rate of growth in height is almost uniform. At 15 it begins to advance more rapidly. At 16 it takes a further advance. But at 17 it falls off by more than one-half, and after that year decreases rapidly.

The same features are observable in the column of weight, except that the increase in the rate begins a year earlier, viz. at 14.

The growth of chest-girth is uniform up to 13, when it becomes double, and then follows nearly the same course as those of height and weight, except that it continues higher at 17 and 18.

The growth of strength follows a more capricious course—doubling itself at 13, making no advance at 14, but making a great stride at 15—continuing longer, and diminishing more slowly than the other heads. The number of observations are at present too few to be fully relied on.

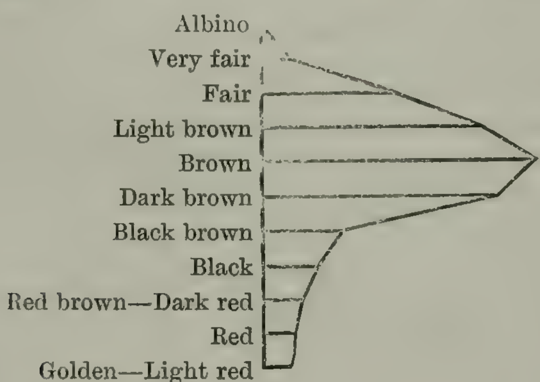
At 14, while the rate of growth in height remains unchanged, there is a large increase in those of weight and chest-girth.

In the second part of the table it will be seen, by comparing the signs + and − at the ages from 15 to 19, and allowing for the irregularity already noticed in the column of strength, the rate of growth in-

creases and decreases at the same period, and with great uniformity of ratio, under all four heads.

III. *As to Colour of Eyes and Hair of Class I.*

In 1027 observations belonging to the standard or first class, the colour of eyes and hair has been recorded. As to the importance and utility of this branch of the inquiry the Committee may refer to Dr. Pruner-Bey's papers, translated in the 'Journal' of the Anthropological Institute, vol. vi. pp. 71–92; to the 'Manual for Anthropologists,' prepared by the lamented Dr. Paul Broca; and to the 'Notes and Queries on Anthropology,' issued by this Association. It may be useful also to direct attention to the valuable practical remarks of Mr. D. Kaltbrunner, in his 'Manuel du Voyageur' (Zurich, 1879), pp. 504, 505. The types for colour of hair are the ten lithographed pages issued by the Committee in 1877 (see Report for that year). Those for colour of eyes were directed to be: grey, light blue, blue, dark blue, light brown, brown, dark brown, green, black—the colour to be viewed at such a distance that minor variations may blend into one general hue and tint. In the subjoined Table the order of the colours is altered for the reasons given below. The extent to which each colour of hair prevails is shown by the following diagram:—



It is to be regretted that the observations are not sufficiently numerous to distinguish young people from adults, as the darkening of hair goes on with advancing age. Dr. Beddoe has found a decided difference between women of 18–23 and women over 25 years, but has observed the greatest change to take place somewhere about 20–23 in men and earlier in women. He states that the associations generally of hair and eye colours shown by the table agree with his own observations; that green eyes do not occur with black hair; nor so-called black eyes with the blackest hair—this last often accompanying dark grey eyes; and that dark blue eyes are rare with reddish hair, but often accompany dark or even black hair, usually in persons of Irish or Scottish Highland extraction. Other interesting associations may be readily traced in Table XI.

Mr. Roberts (by whom Table XI. was prepared) has contributed the following remarks on the colours of hair and eyes:—

'In the instructions issued by the Committee, the colours of the eyes and hair are arranged in a crescendo scale from fair to black, but I have thought it desirable to classify them according to their anatomical and

Class I.—Professional Classes.—Table XI., showing the Colour of Hair and Eyes, and their relation to each other, of 1027 Men and Boys from ages 10 to about 50 years.

Colour of Hair		Colour of Eyes: Light			Mixed		Dark				Total		Percentages	
		Dark blue	Blue	Light blue	Grey	Green	Light brown	Brown	Dark brown	Black				
Light	Very fair	1	9	4	6	1	5	—	—	–	26	487	2·53	57·15
	Fair	2	37	24	44	1	4	5	3	—	120		11·68	
	Light brown	3	49	27	74	14	13	15	1	—	196		19·08	
	Brown	8	37	30	67	23	11	54	13	2	245		23·86	
Dark	Dark brown	9	30	16	59	20	12	41	25	3	215	347	20·93	33·79
	Black-brown	1	5	3	21	6	14	16	11	-	77		7·50	
	Black	3	5	2	8	—	7	14	15	1	55		5·36	
Red	Red-brown	–	5	3	18	4	4	4	—	—	38	93	3·70	9·06
	Red	–	7	1	11	2	4	3	—	—	28		2·73	
	Golden	–	6	6	9	3	2	1	—	—	27		2·63	
Total		27	190	116	317	74	76	153	68	6	1027		100	
			333		391			303						
Percentages		2·62	18·50	11·30	30·87	7·20	7·40	14·90	6·62	·59	100			
			32·42		38·07			29·51						

physiological relations to each other. The iris, on which the colour of the eye depends, is a thin membranous structure composed of unstriped muscular fibres, nerves, and blood-vessels, held together by a delicate network of fibrous tissue. On the inner surface of this membrane there is a layer of dark purple pigment called the *uvea* (from its resemblance to the colour of a ripe grape), and in brown eyes there is an additional layer of yellow (and perhaps brown-red) pigment on its outer surface also, and in some instances there is a deposit of pigment amongst the fibrous structures. In the albino, where the pigment is entirely absent from both surfaces of the iris, the bright red blood is seen through the semitransparent fibrous tissues of a *pink* colour; and in blue eyes, where the outer layer of pigment is wanting, the various shades are due to the dark inner layer of pigment—the *uvea*—showing through fibrous structures of different densities or degrees of opacity. The eyes of new-born infants of both white and black races (and I believe the new-born young of all the lower animals) are dark blue, in consequence of the greater delicacy and transparency of the fibrous portion of the iris; and as these tissues become thickened by use, and by advancing age, the lighter shades of blue, and finally grey are produced; the grey, indeed, being chiefly due to the colour of the fibrous tissues themselves. In grey eyes, moreover, we see the first appearance of the superficial layer of yellow pigment in the form of isolated patches situated around the margin of the pupil, or in rays

running across the iris. In the various shades of green eyes the yellow pigment is more uniformly diffused over the surface of the iris, and the green colour is due to the blending of the superficial yellow pigment with the blue and grey of the deeper structures. In the hazel and brown eyes the *uvea* and the fibrous tissues are hidden by increasing deposits of yellow and brown pigment on the anterior surface of the iris, and when this is very dense black eyes are the result. It is very doubtful, however, whether the iris is ever so dark-coloured in the inhabitants of this country as to justify the term black being applied to it, and the popular use of the expression has reference to the widely dilated pupil common in persons with dark brown eyes. The nearest approach to a black eye among us is the dark blue or violet eye associated with black hair in some Irish adults; here the colour is probably not entirely due, as in infants, to the greater transparency of the fibrous structures, but to interstitial deposit of black pigment, or to a layer situated on the anterior surface of the iris.

'As the observations included in the above table were made by many different persons without specific directions or colour-tests, and as the shades are not well-defined and are too numerous for easy analysis, I have combined them into three large groups—the light, including the shades of blue; the mixed, including the grey and green; and the dark, including the brown and so-called black eyes, in order to correct some obvious errors of observation. Green eyes are more common than the table indicates, and no doubt many cases of green eyes have been recorded as grey, and probably a few as light brown. On the other hand the number of grey eyes appears to be out of proportion to the rest, and this column probably includes a number of light blue as well as grey and green eyes.

'Mr. H. C. Sorby, F.R.S., has examined the colouring matter of the hair,[1] and has separated three pigments which he describes as brown-red, yellow, and black; and he attributes the different shades of the colour of hair to one of these pigments, or to their combination in different proportions. Thus, fair and brown hairs owe their colours chiefly to yellow and black pigment; and the shades of red hair to red and black pigments, the brightest red having the least black or yellow. Acting on these investigations, and bearing in mind that amongst black-haired races red (and not yellow) hair frequently occurs, and is generally associated with black hair in this country, I have interposed the black between the yellow and red shades in the table. This arrangement has the advantage of separating the browns and the reds, and of showing how the black overshadows these colours as the hair darkens by advancing age; and it is useful in distinguishing the chief racial elements of our population. The diagram shows the quantity of hair of each colour, and the relation which the colours bear to each other above the age of 10 years. If the observations commenced at birth, and were grouped in periods of four or five years, the curve would change with advancing age, and the apex would move gradually from the fairer to the darker shades. By grouping the whole of the observations into fair, dark, and red, as I have done in the table, we see the prevailing complexion of the higher and professional classes in this country.'

IV. *As to Town and Country Origin of Class I.*

Though the statistics as yet obtained are not sufficient to show conclusively the different tendencies of town and country life, an attempt has

[1] *Jour. Anthrop. Inst.*, vol. viii.

been made to elicit from the returns of height and weight relatively to age some particulars as to the effect of town and country origin respectively on growth of this class. The means for this is given by the following extract from the General Instructions issued by the Committee with the Forms of Schedule:—

'ORIGIN.—If the individual has lived habitually in the country he should be noted as "*country folk.*" This, however, is not to include residence in large country towns (more than 5000 inhabitants), unless the individual so residing is habitually occupied in country pursuits. If both father and mother are also country folk in the sense above defined the entry should be "*pure country folk.*" In cases where the history of all four grandparents is known, and they or the majority of them were all country folk, the entry should have the word "*very*" prefixed; thus, "very pure country folk." If he is of country birth, but has lived in a town since he was a boy, the entry should be "*c birth, t since boy.*" This form admits of all required variations by writing "p c" or "v p c" instead of "c," and "child," "youth," or "manhood" instead of "boy." As regards other cases, too numerous to attempt to define, in which a doubt may exist as to the proper entry, leave a blank.

'Similar instructions to be observed as regards townsfolk.'

The returns of cadets at Sandhurst, scholars at Westminster, students at Aberystwith, medical students at London Hospital, and scholars at Felstead, afford the means of making this distinction, at ages from ten to thirty, in the following number of cases:—

Country	263	Total of country origin	379
Pure country . . .	40		
Very pure country . .	50		
Country birth, town since	26		
Town	210	Total of town origin .	250
Pure town . . .	17		
Very pure town . .	5		
Town birth, country since	18		
		Total observed	629

The observations give a slight advantage in both height and weight relatively to age to country origin over town origin. Taking the two years of age, eighteen and nineteen, in which there are the largest number of observations in each class to afford an average, the 161 country lads have an average height of 68·2 inches and weight of 141 lbs., while the seventy-nine town lads have an average height of 68·0 inches and weight of 139·5 lbs. The distinction is not so easily followed through the grades of purity in consequence of the small number of observations in some of them, but it seems to prevail, the averages at the two ages named being—

	Height	Weight		Height		Weight
Country . .	68·1	142	Town . .	67·9		139
Pure . .	67·4	138	Pure . .	67·5		136
Very pure .	68·8	142	Very pure .	71	[2 cases only.]	155
Country birth, *town since* .	68·2	139	Town birth, *country since*	68·2		142

These observations being deduced from the standard class present less difference than may be expected from a comparison derived from the peasants and artisans, as persons of this class rarely spend their lives exclusively either in the country or in towns.

The following are full details:—

TABLE XII.—Table showing the Average Height in Inches at each of the undermentioned Ages of Persons of the different grades of Country Origin.

Age	Country Origin									
	Country		Pure Country		Very Pure Country		Country Birth, Town since Boy or Child		All the Grades of Country Origin	
	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches
10–	1	53·5	—	—	—	—	—	—	1	53·5
11–	4	57·0	—	—	—	—	—	—	4	57·0
12–	8	57·5	—	—	—	—	—	—	8	57·5
13–	9	59·5	1	58·5	—	—	—	—	10	59·4
14–	23	62·7	5	62·1	—	—	—	—	28	62·6
15–	23	65·5	4	66·3	2	67·5	—	—	29	65·7
16–	25	66·9	3	67·2	3	66·8	—	—	31	67·0
17–	25	68·1	4	64·8	2	69·5	2	68·5	33	67·8
18–	59	67·4	10	67·9	18	68·4	4	66·8	91	67·7
19–	38	68·8	6	66·8	15	69·2	11	68·6	70	68·7
20–	20	69·1	2	67·0	6	69·1	4	71·0	32	69·2
21–	7	68·6	2	66·0	2	68·5	2	69·0	13	68·3
22–	13	69·1	1	68·5	1	65·5	2	69·0	17	68·9
23–	6	67·7	1	70·5	—	—	1	72·5	8	68·6
24–	1	70·5	1	67·5	1	68·5	1	68·5	4	68·8
25–30	3	70·2	1	66·5	—	—	1	71·5	5	69·7
Total .	265	—	41	—	50	—	28	—	384	—

TABLE XIII.—Table showing the Average Height in Inches at each specified Age of Persons of different grades of Town Origin.

Age	Town Origin									
	Town		Pure Town		Very Pure Town		Town Birth, Country since Boy or Child		All the Grades of Town Origin	
	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches	Number of Observations	Average Height in Inches
10–	1	52·5	—	—	—	—	—	—	1	52·5
11–	3	53·5	—	—	—	—	—	—	3	53·5
12–	6	58·7	1	55·5	—	—	—	—	7	58·2
13–	12	59·9	—	—	—	—	—	—	12	59·9
14–	29	61·2	—	—	1	62·5	—	—	30	61·2
15–	25	64·9	5	64·5	—	—	—	—	30	64·8
16–	25	66·3	—	—	1	66·5	—	—	26	66·3
17–	23	67·5	1	69·5	1	66·5	3	66·5	28	67·4
18–	23	68·0	5	67·1	—	—	5	69·3	33	68·1
19–	35	67·9	4	68·0	2	71·0	5	67·1	46	67·9
20–	13	67·8	—	—	—	—	1	69·5	14	67·9
21–	5	66·7	1	69·5	—	—	2	68·0	8	67·4
22–	4	66·3	—	—	—	—	1	71·5	5	67·3
23–	3	66·5	—	—	—	—	1	67·5	4	66·8
24–	—	—	—	—	—	—	—	—	—	—
25–30	3	68·2	—	—	—	—	—	—	3	68·2
Total .	210	—	17	—	5	—	18	—	250	—

TABLE XIV.—Table showing the Average Weight in Pounds at each of the undermentioned Ages of Persons of different grades of Country Origin.

Age	Country Origin									
	Country		Pure Country		Very Pure Country		Country Birth, Town since Boy or Child		All the Grades of Country Origin	
	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds
10–11	1	72·5	—	—	—	—	—	—	1	72·5
11–	4	72·5	—	—	—	—	—	—	4	72·5
12–	8	77·5	—	—	—	—	—	—	8	77·5
13–	9	90·3	1	92·5	—	—	—	—	10	90·5
14–	23	103·6	5	102·5	—	—	—	—	28	103·4
15–	23	114·7	4	116·3	2	112·5	—	—	29	114·7
16–	25	125·5	3	130·8	2	127·5	—	—	30	126·2
17–	24	136·0	4	115·0	2	142·5	2	142·5	32	134·2
18–	59	135·0	10	140·0	18	142·5	4	135·0	91	137·1
19–	39	148·4	6	135·8	15	142·2	9	143·6	69	145·3
20–	20	147·8	2	142·5	6	147·5	4	168·7	32	150·0
21–	7	147·5	2	142·5	2	152·5	2	150·0	13	147·9
22–	11	154·8	1	147·5	1	132·5	2	155·0	15	152·8
23–	6	149·2	1	162·5	—	—	1	152·5	8	151·3
24–	1	147·5	1	162·5	1	157·5	1	162·5	4	157·5
25–30	3	167·5	—	—	1	132·5	1	177·5	5	162·5
Total .	263	—	40	—	50	—	26	—	379	—

TABLE XV.—Table showing the Average Weight in Pounds at each specified Age of Persons of different grades of Town Origin.

Age	Town Origin									
	Town		Pure Town		Very Pure Town		Town Birth, Country since Boy or Child		All the Grades of Town Origin	
	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds	Number of Observations	Average Weight in Pounds
10–	1	67·5	—	—	—	—	—	—	1	67·5
11–	3	60·8	—	—	—	—	—	—	3	60·8
12–	6	78·3	1	77·5	—	—	—	—	7	78·2
13–	14	85·4	—	—	—	—	—	—	14	85·4
14–	29	94·2	—	—	1	107·5	—	—	30	94·7
15–	26	114·6	4	116·3	—	—	—	—	30	114·8
16–	25	123·5	—	—	1	132·5	—	—	26	123·8
17–	23	133·4	1	132·5	1	117·5	3	120·8	28	131·4
18–	23	136·4	5	133·5	—	—	5	145·5	33	137·3
19–	34	141·6	4	138·8	2	155·0	5	138·5	45	141·6
20–	10	147·5	—	—	—	—	1	147·5	11	147·5
21–	5	144·5	1	152·5	—	—	2	152·5	8	147·5
22–	4	135·0	—	—	—	—	1	162·5	5	140·5
23–	3	135·8	—	—	—	—	1	142·5	4	137·5
24–	—	—	—	—	—	—	—	—	—	—
25–30	5	134·5	—	—	—	—	—	—	5	134·5
Total .	211	—	16	—	5	—	18	—	250	—

TABLE XVI.—Table showing the Average Height and Weight at each Age of Persons of all grades of Country Origin, of all grades of Town Origin, and of all grades of Town and of Country Origin.

Age	All the Grades of Country Origin			All the Grades of Town Origin			Total of all Grades		
	No. Obs.	Height Inches	Weight Pounds	No. Obs.	Height Inches	Weight Pounds	No. Obs.	Height Inches	Weight Pounds
10–	1	53·5	72·5	1	52·5	67·5	2	53·0	70·0
11–	4	57·0	72·5	3	53·5	60·8	7	55·4	67·5
12–	8	57·5	77·5	7	58·2	78·2	15	57·8	77·8
13–	10	59·4	90·5	14	59·9	85·4	24	59·7	87·5
14–	28	62·6	103·4	30	61·2	94·7	58	61·9	98·9
15–	29	65·7	114·7	30	64·8	114·8	59	65·2	114·8
16–	30	67·0	126·2	26	66·3	123·8	56	66·7	125·1
17–	32	67·8	134·2	28	67·4	131·4	60	67·6	132·9
18–	91	67·7	137·1	33	68·1	137·3	124	67·8	137·1
19–	69	68·7	145·3	45	67·9	141·6	178	68·4	143·9
20–	32	69·2	150·0	11	67·9	147·5	43	68·8	149·4
21–	13	68·3	147·9	8	67·4	147·5	21	67·9	147·7
22–	15	68·9	152·8	5	67·3	140·5	20	68·5	149·8
23–	8	68·6	151·3	4	66·8	137·5	12	68·0	146·7
24–	4	68·8	157·5	—	—	—	4	68·8	157·5
25–30	5	69·7	162·5	5	68·2	134·5	10	69·1	148·5
10 and under 13	13	57·0	75·6	11	56·4	72·5	24	56·8	74·2
13 ,, 16	67	63·5	106·4	74	62·5	101·1	141	63·0	103·6
16 ,, 19	153	67·5	134·3	87	67·4	131·4	240	67·5	133·3
19 ,, 22	114	68·8	146·9	64	67·9	143·4	178	68·4	145·6
22 ,, 25	27	68·8	153·1	9	67·1	139·2	36	68·4	149·6
25 ,, 30	5	69·7	162·5	5	68·2	134·5	10	69·1	148·5

MEM.—Comparing the two columns headed 'All Grades of Country Origin' and 'All Grades of Town Origin,' it will be observed that those of country origin have in nearly every case an advantage in height and weight over those of town origin; and on referring to the table at foot, where the results are given in periods of three years, this will be still more noticeable.

V. *As to Growth.*

One very interesting branch of the inquiry with which your Committee is charged is the annual development of young people of both sexes; but the opportunity of obtaining such information continued over a considerable number of years is very rare, and the Committee have as yet been able to procure only one return of this nature. It relates to the yearly growth of a small number of children of American parents, presented by Dr. Bowditch, Professor of Physiology in Harvard Medical School. But they are of opinion that the publication of it, and of some results which have been deduced from it by the Committee, may be useful in suggesting to persons who are in possession of similar observations, however few in number, and limited in period of record, to communicate them to the Committee. Many parents take the height of their children periodically; a few perhaps take their weight also. An examination of Tables XVII. and XVIII., and the remarks thereon, will show to what good account a collocation and comparison of such facts may be turned.

Table XVII. is a comparative statement abstracted by Sir Rawson Rawson from Dr. Bowditch's original table, of which Table XVIII. is a copy.

TABLE XVII.—Comparative Statement of the Annual Growth of a certain number of American Boys and Girls (12 boys and 13 girls) as far as recorded, from birth to 22 years of age, abstracted from the following Table.

Years	Number of Cases		Average Height in Inches		Annual Growth in Inches					
					Males			Females		
	Males	Females	Males	Females	Max.	Min.	Average	Average	Max.	Min.
From birth to 1 year	—	1	—	23·	—	—	—	8·1	—	—
" 1 year " 2 years	8	7	29·1	27·8	5·	2·5	3·72	4·13	5·3	2·8
" 2 years " 3 "	8	8	32·3	31·6	5·3	2·5	3·52	3·74	5·1	2·7
" 3 " " 4 "	8	9	36·3	35·6	4·4	1·4	2·78	2·97	3·7	2·1
" 4 " " 5 "	9	10	39·5	38·3	3·3	1·5	2·42	2·52	2·9	1·9
" 5 " " 6 "	10	10	42·1	40·9	3·1	1·1	2·50	2·41	3·1	1·7
" 6 " " 7 "	10	11	44·6	43·5	2·9	1·3	2·26	2·42	2·9	1·7
" 7 " " 8 "	12	11	46·6	45·8	3·6	2·1	2·61	2·34	2·8	2·
" 8 " " 9 "	12	12	49·3	48·5	4·	1·4	2·33	2·23	3·	1·3
" 9 " " 10 "	12	12	51·6	50·6	2·3	1·4	1·84	2·11	2·8	1·4
" 10 " " 11 "	12	12	53·5	52·7	2·2	1·5	1·91	2·18	2·6	·7*a*
" 11 " " 12 "	12	13	55·5	54·8	2·5	1·2	1·88	2·70	6·1*a*	1·4
" 12 " " 13 "	11	13	57·3	57·	3·9	·9	2·04	3·07	4·9*b*	2·3
" 13 " " 14 "	11	13	59·5	60·3	4·7	1·1	2·52	1·95	3·3	·9*b*
" 14 " " 15 "	11	13	62·	62·2	3·9	1·7	2·36	1·29	3·5	·1
" 15 " " 16 "	11	12	64·2	63·5	3·8	·5	2·31	·76	1·3	·0
" 16 " " 17 "	10	12	66·4	63·8	2·5	·5	1·45	·61	1·4	·1
" 17 " " 18 "	9	11	68·3	64·7	2·3	·1	·98	·21	·7	·0
" 18 " " 19 "	8	6	69·	64·9	1·8	·1	·76	·49	·7	·15
" 19 " " 20 "	7	3	70·5	65·2	1·0	Nil	·26	·43	·9	·2
" 20 " " 21 "	5	—	70·7	66·2	·45	·05	·25	—	—	—
" 21 " " 22 "	3	—	70·9	—	·45	·05	·27	—	—	—

a. The same girl. *b.* The same (another) girl.

The accompanying charts, Nos. II. and III. (Plates V. and VI.), show tracings of Prof. Bowditch's observations on the successive growth in stature of twelve boys and thirteen girls nearly related in blood and of the professional class. The tracings for each individual cannot be followed throughout on account of the intersections and overlapping which occur, but they are sufficiently distinct to show the relative course which each and all have run. A marked feature in the charts when compared together is the greater regularity and parallelism of the growth of girls, especially at the earlier periods of life. From this it is obvious that the physical development of boys is subject to more powerful modifying agencies than that of girls, which is attributable to the more varied lives boys lead, and to the lower degree of viability which they possess even from the period of birth. Some of the irregularities shown by the tracings are probably due to slight errors of observation, but the deviations in direction are clearly due to external causes; if the tracings had been made at the time the measurements were taken, and the apparent causes of the deviations had been recorded, we should possess some very interesting charts of the physical history of each individual, and many useful facts illustrating the influence of *media* on the growth of the human body.

TABLE XVIII.—Table showing the Height and Annual Growth (in feet, inches,
Bowditch, Professor of Physiology

Females	Age last										
	Birth	1	2	3	4	5	6	7	8	9	10
Lillie . .	—	—	—	—	—	—	—	—	—	—	—
Mary . .	—	—	—	—	—	—	—	—	4–0·0	4–2·3	4–4·
Alice . . .	—	2–5·	2–7·8	2–11·	3–1·1	3–3·7	3–6.5	3–8·7	3–10·8	—	4–3·
Charlotte .	—	2–4·	2–9·	3–0·8	3–3·9	3–6·8	3–8·9	3–11·6	4–2·1	4–3·4	4–6·
Lucy . . .	—	2–4·5	2–9·3	3–0·7	3–3·7	3–6·6	3–8·8	3–10·6	4–1·1	4–3·7	4–6·
Lily . . .	1–11·	2–7·1	2–10·	3–1·2	3–4·1	3–6·4	3–9·2	3–11·6	4–2·0	4–4·3	4–6·2
Livy . . .	—	—	—	—	3–1·8	3–4·2	3–6·8	3–8·5	3–11·0	4–2·0	4–4·1
Fanny . .	—	—	—	—	—	—	3–9·4	4–0·3	4–2·5	4–4·1	4–6·9
Esther . .	—	—	—	3–0·4	3–3·1	3–5·6	3–7·3	3–9·5	3–11·5	4–1·8	4–4·3
Susan . .	—	—	2–5·6	2–9·8	3–0·8	3–3·2	3–6·3	3–8·7	3–11·1	4–1·7	4–3·6
Arria . .	—	2–1·	2–6·3	2–11·4	3–2·3	3–4·8	3–6·7	3–9·6	—	4–1·9	4–3·8
Mary . .	—	2–2·6	2–6·5	—	3–1·4	3–4·2	3–6·4	3–8·7	—	4–2·3	4–3·7
Annie . .	—	2–2·8	2–6·3	2–10·6	3–1·4	3–3·3	3–6·0	3–8·1	3–10·3	4–0·6	4–2·8
Average Height	—	2–3·8	2–7·6	2–11·7	3–2·4	3–4·9	3–7·5	3–9·8	4–0·5	4–2·6	4–4·7
Annual Increase	—	—	3·8	4·1	2·7	2·5	2·6	2·3	2·7	2·1	2·1
Males											
Frank . .	—	—	—	—	—	3–7·8	3–10·7	4–1·4	4–4·4	4–7·	4–8·8
Henry . .	—	—	—	—	—	—	—	3–8·4	3–10·9	4–1·3	4–3·2
Charles . .	—	—	—	—	3–6·2	3–9.0	4–0·	4–2·3	4–4·9	4–7·5	4–9·4
Alfred . .	—	2–8·3	3–0·6	3–3·8	3–6·7	3–9·0	3–11·8	4–2·2	4–4·7	4–7·3	4–9·3
Nat . . .	—	—	—	—	—	—	—	3–11·	4–1·7	4–3·2	4–5·
Ned . . .	—	2–4·3	2–9·	3–0·	3–2·3	3–5·6	3–7·7	3–9·8	4–0·	4–2·3	4–4·2
Vin . . .	—	2–8·2	3–0·	3–3·2	3–5·6	3–7·3	3–10·0	4–0·3	4–2·7	4–5·4	4–7·0
James . .	—	2–2·2	2–4·7	2–10·	3–2·4	3–5·5	3–7·8	3–10·7	4–0·8	4–4·8	4–6·6
Ernest . .	—	2–4·	2–9·	2–11·9	3–3·8	3–5·9	3–8·2	3–11·	4–1·7	4–3·4	4–4·8
John . . .	—	2–4·	2–8·	3–0·3	3–2 5	3–5·3	3–8·4	3–10·3	4–0·6	4–2·0	4–4·3
Arthur . .	—	2–5·	2–7·5	2–10·	2–11·4	3–1·6	3–2·7	3–4·	3–7·6	3–10·	4–0·
Basil . . .	—	2–5·	2–8·	2–11·8	3–2·5	3–4·0	3–6·7	3–8·6	3–11·4	4–1·4	4–3·1
Average Height	—	2–5·1	2–9·5	3–0·3	3–3·5	3–6·1	3–8·6	3–10·6	4–1·3	4–3·6	4–5·5
Annual Increase	—	—	4·4	2·8	3·2	2·6	2·5	2·0	2·7	2·3	1·9

NOTE.—The measurements were all taken annually during the last 25 years, and the
1872, and The Growth of Children, 'Eighth Ann.

and tenths) from year to year of 25 children of both sexes. By Dr. H. P.
at Harvard Medical School.

Birthday												
11	12	13	14	15	16	17	18	19	20	21	22	
4–4·6	4–6.1	4–11·	4–11·9	5–2·3	5–3·6	5–4·2	5–4·7	5–5·1	5–5·3	—	—	
4–4·7	4–10·8	5–1·4	5–2·6	5–3·	5–3·	5–3.3	5–3·6	—	—	—	—	
4–5·3	4–8·4	4–11·5	—	5–3·4	5–4·5	5–4·6	—	5–5·3	5–6·	—	—	
4–8·5	4–10·8	5–2·1	5–4·6	—	—	5–6·3	—	5–6·9	5–7·8	—	—	
4–8·3	4–10·5	5–0·9	5–4·	5–4·7	5–5·6	5–7·	5–7·3	—	—	—	—	
4–8·2	4–10·	5–0·4	5–3·7	5–5·1	5–5·6	5–6·4	5–6·6	—	—	—	—	
4–6·7	4–10·3	5–0·8	5–2·3	5–3·2	5–3·9	—	5–4·2	5–4·9	—	—	—	
4–9·3	5–0·2	5–2·7	5–4·	5–4·7	—	5–5·	5–5·	5–5·7	5–5·9	—	—	
4–6·5	4–9·5	4–11·8	5–0·9	—	5–1·1	5–2·3	5–2·4	—	—	—	—	
4–6·2	4–9·5	4–11·8	5–1·3	5–1·8	5–1·2	5–3·	—	5–3·3	—	—	—	
4–6·3	4–8·5	—	5–2·1	5–4·2	—	—	—	—	—	—	—	
4–5·6	4–7·	4–11·	5–0·	5–3·5	5–4·4	5–4·6	—	—	—	—	—	
4–5·	4–6·9	4–10·	5–1·2	5–2·8	5–4·2	5–5·2	5–5·2	—	—	—	—	
4–6·8	4–9·	5–0·3	5–2·2	5–3·5	5–3·8	5–4·7	5–4·9	5–5·2	5–6·2	—	—	feet & inches
2·1	2·4	3·3	1·9	1·3	0·3	0·9	0·2	0·3	1·0	—	—	inches
4–10·8	5–0·	5–2·9	5–7·6	5–9·3	5–9·8	5–10·4	5–10·5	5–11·3	5–11·4	5–11·6	—	
4–5·0	4–7·2	4–9·	4–11·	5–1·4	5–4·7	5–7·2	5–8·8	5–9·5	5–9·8	5–10·	—	
4–11·2	5–1·1	5–3·	5–4·4	5–6·3	5–9·2	5–11·3	6–0·8	6–0·9	6–1·	—	—	
4–11·4	5–1·2	5–2·8	5–4·5	—	5–8·4	—	—	—	—	—	—	
4–7·	4–9·5	4–11·3	5–1·	5–3·2	5–5·6	5–7·7	5–10·	5–10·8	5–10·9	5–11·	5–11·3	
4–5·8	4–7·9	4–9·9	5–1·	5–4·9	5–8·7	5–9·2	5–9·4	5–10·	5–10·	—	5–10·1	
4–9·2	4–11·3	5–3·2	5–6·8	5–8·8	—	5–10·5	—	—	—	—	—	
4–8·5	4–10·	4–10·9	5–2·9	5–4·7	—	5–8·	5–8·7	5–9·	5–9·2	—	5–9·9	
4–7·0	4–9·2	4–11·5	5–1·7	5–4·2	5–7·5	—	5–9·6	5–10·6	—	—	—	
—	4–7·4	4–9·2	4–10·3	5–1·4	5–3·7	—	5–8·	5–9·8	5–10·8	—	—	
4–2·1	4–4·0	4–5·4	4–7·6	4–10·1	5–0·6	5–2·6	5–3·4	—	—	—	—	
4–5·	4–6·8	—	—	—	—	—	—	—	—	—	—	
4–7·5	4–9·3	4–11·5	5–2·	5–4·2	5–6·4	5–8·3	5–9·	5–10·5	5–10·7	5–10·9	5–10·4	feet & inches
2·0	1·8	2·2	2·5	2·2	2·2	1·9	0·7	1·5	0·2	0·2	—	inches

individuals were all nearly related to each other. See 'Boston Med. & Surgical Journal,' Dec.
Rep. of the State Board of Health of Mass.,' 1877.

Remarks on Table XVIII.

The number of persons observed in the above tables is too small to admit of drawing any positive conclusions from the data; but it is hoped that they may be confirmed, or corrected, by other independent observations.

1° The average growth of the girls in each year from 1 to 5 exceeds that of the boys, but in a decreasing ratio, viz.:—

In 2nd year, viz.:	from 1 to 2	—excess of girls—	8·3	per cent.
3rd „	„ 2 „ 3	„ „	6·2	„
4th „	„ 3 „ 4	„ „	6·1	„
5th „	„ 4 „ 5	„ „	4·1	„
		Average .	6·6	

2° From 5 to 6 the scale inclines slightly in favour of the boys, viz.: 3·7 %; but as from 6 to 7 it turns back again, being 7 % in favour of the girls, it may be assumed that the deviation was accidental, and that from 1 to 7 years of age the growth of the girls exceeds that of the boys, the average excess of the whole period being 5·2 %.

3° From 7 to 9 the scale turns decidedly in favour of the boys, being 8·1 % in excess, but from 9 to 13 there is a marked excess in favour of the girls, viz.:—

		Excess of Girls	
In 10th year, viz.:	from 9 to 10	—14·6 per cent.	Average 31·1 per cent.
11th „	„ 10 „ 11	—14·1 „	
12th „	„ 11 „ 12	—43·6 „	
13th „	„ 12 „ 13	—50·5 „	

4° The great excess between 11 and 13 is the more remarkable, as after the latter year the scale turns in favour of the boys, and continues up to 19, when the number of observations is too small to admit of any conclusion being drawn from what may have been an accidental change.

		Excess of Boys	
In 14th year, viz.:	from 13 to 14	— 29·2 per cent.	Average 95·4 per cent.
15th „	„ 14 „ 15	— 82·9 „	
16th „	„ 15 „ 16	—203·9 „	
17th „	„ 16 „ 17	—137·7 „	
18th „	„ 17 „ 18	—366·6 „	
19th „	„ 18 „ 19	— 55·1 „	

5° From the above it will be seen that

From 1 to 7	the growth is	slightly in favour of	girls, viz.:	5·2	per cent.
„ 7 „ 9	„	„ „	boys, „	8·1	„
„ 9 „ 11	„	moderately „	girls, „	14·4	„
„ 11 „ 13	„	largely „	„ „	47·2	„
„ 13 „ 15	„	„ „	boys, „	50·6	„
„ 15 „ 18	„	immensely „	„ „	200·0	„

With regard to the last proportion the fact is that while at the age of 12 the annual growth among the boys begins to increase—averaging about that which they made between 4 and 9—it decreases rapidly among the girls. The total increase from 15 to 19 among the boys was 5·76 inches, and among the girls only 2·50 inches.

6° In comparing the maxima and minima growths of the two sexes, there appear to be in the former no very marked features up to the age of 11.

	Boys	Girls	
From 1 to 3 they are equal, viz.:	5·2	5·2	inches
„ 3 „ 5 a slight excess among boys, averaging annually	3·8 to	3·3	„
„ 5 „ 7 exactly equal	3·	3·	„
„ 7 „ 9 an excess among boys	3·8	2·9	„
„ 9 „ 11 „ „ girls	2·2	2·7	„

At 11 to 13 there are in this table two cases of unusual growth among the girls, viz., 6·1 and 4·9 inches in one year respectively; and it is remarkable that in the first case the girl grew only 0·7 inch in the preceding year, and in the second case the girl (a different one) grew only 0·9 inch in the succeeding year. No such remarkable case occurred among the boys. After eliminating these two cases, the excess in this period remains in favour of the girls, but after 13 it preponderates greatly among the boys:—

	Boys	Girls	
From 11 to 13 the excess among the girls, averaging annually	3·2 to	4·1	inches
„ 13 „ 17 „ „ boys, „ „	3·7 „	2·4	„
„ 17 „ 20 „ „ „ „ „	1·7 „	0·8	„

7° Treating the minima in the same way, those of the boys are uniformly lower than those of the girls up to the age of 7, viz.:—

	Boys	Girls	
From 1 to 7 the excess among the girls, averaging annually	1·7 to	2·1	inches
„ 7 „ 11 „ „ boys, „ „	1·6 „	1·3	„

At 11 to 13 the minima of the girls are, like their maxima, exceptional; showing that in these two years the growth of girls is not only exceptionally, but at both ends of the scale usually, in excess of that of boys.

	Boys	Girls	
From 11 to 13 the excess among the girls, averaging annually	1·0 to	1·8	inches
„ 13 „ 19 „ „ boys, „ „	0·7 „	0·2	„

8° The following table would be of considerable interest if it were based on a larger number of cases. As far as it goes, it shows that in both sexes a rapid annual growth, of 3 inches or more, occurs chiefly between the ages of 1 to 3 and 11 to 16, the proportion being greater among girls at the latter age, while it is greater among boys between 4 and 11.

Number of Cases of Rapid Growth at Different Ages.

Ages	Boys				Girls				
	3 to 4 inches	4 to 5 inches	5 to 6 inches		3 to 4 inches	4 to 5 inches	5 to 6 inches	Above 6 inches	
At 1	2	3	1		1	1	2	0	
„ 2	4	1	1	15	3	2	1	0	13
„ 3	2	1	0		3	0	0	0	
„ 4	1	0	0		0	0	0	0	
„ 5	2	0	0		1	0	0	0	
„ 6	1	0	0		0	0	0	0	
„ 7	1	0	0	6	0	0	0	0	2
„ 8	0	1	0		1	0	0	0	
„ 9	0	0	0		0	0	0	0	
„ 10	0	0	0		0	0	0	0	
„ 11	0	0	0		5	0	0	1	
„ 12	1	0	0		1	3	0	0	
„ 13	2	2	0	10	3	0	0	0	14
„ 14	2	0	0		1	0	0	0	
„ 15	2	0	0		0	0	0	0	
„ 16	1	0	0		0	0	0	0	

Percentage Proportion of above in Three Periods.

	Boys	Girls
From 1 to 3	48·4	44·8
„ 4 „ 10	19·4	6·9
„ 11 „ 16	32·2	48·3
Total	100·	100·

The importance of the period between 11 and 13 among girls is again illustrated by the above comparison.

9° Of continuous rapid growth the instances were not numerous, but they were more striking among the girls, and chiefly at an early age.

Boys in 3 years from	1 to 3	1 grew	10·5 inches
		1 „	11·8 „
		1 „	12·2 „
„ 2 „	12 „ 14	1 „	7·5 „
„ „	14 „ 16	1 „	7·7 „
Girls in 3 „	1 „ 3	1 „	10·6 „
		1 „	10·8 „
		1 „	11·2 „
		1 „	11·9 „
„ 2 „	1 „ 3	1 „	10·4 „
„ 2 „	11 „ 13	1 „	8·7 „
„ 2 „	12 „ 14	1 „	8·1 „

10° The following table would be of much value if the observations were more numerous. The periods have been divided according to evident changes in the average growth of one or both sexes. It will not escape remark that the average growth of both sexes between 3 and 9 was exactly equal.

		Boys	Girls	
From 1 to 3	average annual growth	3·61	3·87	inches
„ 3 „ 9	„ „	2·48	2·48	„
„ 9 „ 11	„ „	1·87	2·14	„
„ 11 „ 13	„ „	1·97	2·88	„
„ 13 „ 17	„ „	2·16	1·15	„
„ 17 „ 20	„ „	0·66	0·38	„

The more general, but not less valuable, remarks of Professor Bowditch on his original table, published in the 'Boston Medical and Surgical Journal' of December 19, 1872, are as follows :—

'The measurements were all taken annually during the last twenty-five years, and the individuals were all nearly related to each other. An examination of the curves shows the following facts :—

'1. Growth is most rapid during the earliest years of life.

'2. During the first twelve years boys are from one to two inches taller than girls of the same age.

'3. At about twelve and a half years of age girls begin to grow faster than boys, and, during the fourteenth year, are about one inch taller than boys of the same age.

'4. At fourteen and a half years of age boys again become the taller, girls having, at this period, very nearly completed their growth, while boys continue to grow rapidly till 19 years of age.'

The Committee adds the following table illustrative of the greater weight as well as height of girls during a critical period of life, abstracted from Mr. Roberts's paper on 'Factory Children' (1876).

TABLE XIX.—Table showing the relative HEIGHT and WEIGHT of Boys and Girls in England at the age of 13–14 years. (C. Roberts.)

Class of Children	Height.					
	Boys		Girls		Difference	
	No.	Inches	No.	Inches	Boys	Girls
Stanway, 1833, Factory Children	45	54·48	63	55·64	—	1·16
„ 1833, Non-factory „	22	54·98	18	55·07	—	0·09
Ferguson, 1871–3, Factory „	—	—	—	—	—	—
Roberts, 1873, Non-factory „	24	55·21	14	56·08	—	0·87

Class of Children	Weight					
	Boys		Girls		Difference	
	No.	lbs.	No.	lbs.	Boys	Girls
Stanway, 1833, Factory Children	45	72·11	63	73·25	—	1·14
„ 1833, Non-factory „	22	75·36	18	72·72	2·63	—
Ferguson, 1871–3, Factory „	494	68·72	542	70·25	—	1·53
Roberts, 1873, Non-factory „	35	76·48	27	77·58	—	1·10

VI. *Marlborough College Statistics.*

Though it does not in any degree enter into the contemplation of the Committee to discuss the returns of any particular college or establishment in detail, and indeed it would be foreign to their purpose to furnish the means of comparison that might be invidious between one institution and another, the series of 1850 observations made during several years by Dr. Fergus on boys in Marlborough College, and communicated to the Committee by the Rev. T. A. Preston, have been thought by the Committee to constitute an exception, and it has been considered advisable to prepare abstracts of them as affording an excellent example of the usefulness of systematic records. These have been prepared by Sir Rawson W. Rawson for each quarter of a year of age, in the same manner as those of the boys at Christ's Hospital, contained in the Committee's last Report. See Tables XX. to XXIII., to which are added tables of head-girth, arm-girth, and leg-girth (XXIV.–XXVI.) prepared by Mr. Roberts.

TABLE XX.—Statement of the HEIGHT, without shoes, of Boys in Marlborough College, showing the average, maximum, and minimum at each year and quarter of a year of age, between 9 and 20. (Taken in 1874–78.)

Age in Quarters of Years	No. of Observations	Height in Inches and Decimals				
		Quarterly			Yearly	
		Average	Maximum	Minimum	No. of Observations	Average
9	1	51	—	—	6	53·7
9¼	—	—	—	—		
9½	2	54	54·2	53·6		
9¾	3	56·2	57·2	54·6		
	Average of Quarterly Averages		55·6	54·2		
10	4	54·7	55·4	54·0	25	54·4
10¼	6	53·8	56·4	51·6		
10½	8	55·4	57·6	52·0		
10¾	7	53·8	57·2	49·4		
	Average of Quarterly Averages		56·6	51·6		
11	18	54·7	62·4	49·4	84	56·0
11¼	16	56·3	67·0	51·2		
11½	26	56·7	61·2	52·2		
11¾	24	56·5	60·4	48·2		
	Average of Quarterly Averages		62·6	50·2		
12	37	57·0	62·2	52·0	208	57·3
12¼	54	57·3	70·0	53·6		
12½	50	57·9	61·6	52·6		
12¾	67	57·2	64·0	52·4		
	Average of Quarterly Averages		64·4	52·6		
13	80	57·4	65·0	51·6	333	58·7
13¼	77	59·3	68·2	54·4		
13½	96	59·0	71·2	54·6		
13¾	80	59·2	67·4	49·6		
	Average of Quarterly Averages		68·0	52·5		
14	110	60·8	68·2	54·2	367	61·4
14¼	79	61·4	68·0	54·0		
14½	97	61·2	69·0	51·2		
14¾	81	62·2	68·4	56·0		
	Average of Quarterly Averages		68·3	53·7		

TABLE XX.—STATEMENT OF THE HEIGHT, &c.—*continued.*

Age in Quarters of Years	No. of Observations	Height in Inches and Decimals				
		Quarterly			Yearly	
		Average	Maximum	Minimum	No. of Observations	Average
15	85	62·4	69·6	55·4	315	63·4
15¼	78	62·7	70·0	54·0		
15½	69	64·1	70·0	57·2		
15¾	83	64·4	73·5	55·0		
	Average of Quarterly Averages		70·6	55·3		
16	77	65·1	70·6	57·7	283	65·6
16¼	75	65·6	72·0	59·4		
16½	73	65·1	70·4	54·6		
16¾	58	66·8	72·2	60·0		
	Average of Quarterly Averages		71·3	58·8		
17	46	67·4	72·6	60·3	148	67·5
17¼	46	67·0	73·0	57·4		
17½	26	67·7	71·4	62·4		
17¾	30	68·0	76·4	62·4		
	Average of Quarterly Averages		73·3	60·7		
18	27	67·7	71·0	63·4	59	68·5
18¼	16	69·7	72·4	64·7		
18½	9	67·5	70·2	63·4		
18¾	7	69·3	71·2	65·2		
	Average of Quarterly Averages		71·2	64·0		
19	9	67·9	73·4	63·0	20	67·4
19¼	5	66·3	66·6	66·0		
19½	5	67·5	68·4	65·4		
19¾	1	68·0	—	—		
	Average of Quarterly Averages		69·3	63·5		
20	2	62·7	67·0	58·4	2	62·7

TABLE XXI.—Statement of the WEIGHT of Boys in Marlborough College, showing the average, maximum, and minimum at each year and quarter of a year of age, between 9 and 20. (Taken in 1874–78.)

Age in Quarters of Years	No. of Observations	Weight in lbs. and Decimals: Quarterly: Average	Quarterly: Maximum	Quarterly: Minimum	Yearly: No. of Observations	Yearly: Average
9	1	75·0	—	—	6	77·0
$9\frac{1}{4}$	—	—	—	—		
$9\frac{1}{2}$	2	76·5	79·0	74·0		
$9\frac{3}{4}$	3	79·3	82·0	75·0		
	Average of Quarterly Averages		80·5	74·5		
10	4	74·2	81·0	68·0	25	73·3
$10\frac{1}{4}$	6	71·5	79·0	69·0		
$10\frac{1}{2}$	8	76·2	91·0	63·0		
$10\frac{3}{4}$	7	71·5	79·0	63·0		
	Average of Quarterly Averages		82·5	65·7		
11	18	76·3	98	56	84	79·4
$11\frac{1}{4}$	16	77·0	88	63		
$11\frac{1}{2}$	26	85·0	102	71		
$11\frac{3}{4}$	24	79·3	104	67		
	Average of Quarterly Averages		98·0	63·7		
12	37	83·9	103	65	208	84·7
$12\frac{1}{4}$	54	83·6	109	62		
$12\frac{1}{2}$	50	86·3	108	69		
$12\frac{3}{4}$	67	85·6	115	58		
	Average of Quarterly Averages		108·7	63·5		
13	80	90·9	133	64	333	92·3
$13\frac{1}{4}$	77	92·3	144	74		
$13\frac{1}{2}$	96	93·7	125	70		
$13\frac{3}{4}$	80	92·4	127	58		
	Average of Quarterly Averages		132·2	66·5		
14	110	98·2	163	74	367	101·5
$14\frac{1}{4}$	79	100·5	141	75		
$14\frac{1}{2}$	97	102·7	140	64		
$14\frac{3}{4}$	81	104·7	146	75		
	Average of Quarterly Averages		147·5	72·0		

TABLE XXI.—STATEMENT OF THE WEIGHT, &c.—*continued.*

Age in Quarters of Years	No. of Obser-vations	Weight in lbs. and Decimals				
		Quarterly			Yearly	
		Average	Maximum	Minimum	No. of Obser-vations	Average
15	85	108·9	142	84	315	113·2
$15\frac{1}{4}$	78	110·2	168	73		
$15\frac{1}{2}$	69	117·2	151	86		
$15\frac{3}{4}$	83	116·7	186	74		
	Average of Quarterly Averages		161·7	79·2		
16	77	122·7	161	88	283	127·0
$16\frac{1}{4}$	75	126·2	173	91		
$16\frac{1}{2}$	73	128·0	179	76		
$16\frac{3}{4}$	58	131·4	174	100		
	Average of Quarterly Averages		171·7	88·7		
17	46	132·0	173	94	148	136·3
$17\frac{1}{4}$	46	133·9	164	95		
$17\frac{1}{2}$	26	142·5	201	116		
$17\frac{3}{4}$	30	136·9	175	106		
	Average of Quarterly Averages		178·2	102·7		
18	27	140·6	158	104	59	144·1
$18\frac{1}{4}$	16	145·8	179	124		
$18\frac{1}{2}$	9	150·7	210	127		
$18\frac{3}{4}$	7	139·3	157	118		
	Average of Quarterly Averages		176·0	120·7		
19	9	141·0	160	121	20	140·0
$19\frac{1}{4}$	5	134·8	144	126		
$19\frac{1}{2}$	5	140·0	149	134		
$19\frac{3}{4}$	1	144·0	—	—		
	Average of Quarterly Averages		151·0	127·0		
20	2	116	139	93	2	116·0

TABLE XXII.—Statement of the CHEST-GIRTH of Boys in Marlborough College, showing the average, maximum, and minimum at each year and quarter of a year of age, between 9 and 20. (Taken in 1874-78.)

Age in Quarters of Years	No. of Observations	Chest-girth in Inches and Decimals				
		Quarterly			Yearly	
		Average	Maximum	Minimum	No. of Observations	Average
9	1	29	—	—	6	27·4
$9\frac{1}{4}$	—	—	—	—		
$9\frac{1}{2}$	2	26·2	26·7	26·0		
$9\frac{3}{4}$	3	27·0	29·0	26·2		
	Average of Quarterly Averages		27·8	26·1		
10	4	26·5	27·6	26·0	25	26·1
$10\frac{1}{4}$	6	26·6	27·0	24·4		
$10\frac{1}{2}$	8	26·3	28·2	25·0		
$10\frac{3}{4}$	7	25·1	26·4	21·2		
	Average of Quarterly Averages		27·3	24·1		
11	18	26·5	30·0	21·4	84	27·0
$11\frac{1}{4}$	16	27·0	29·0	25·0		
$11\frac{1}{2}$	26	27·3	31·0	25·0		
$11\frac{3}{4}$	24	27·1	30·0	25·0		
	Average of Quarterly Averages		30·0	24·1		
12	37	26·6	29·6	25·0	208	27·0
$12\frac{1}{4}$	54	27·0	29·4	25·0		
$12\frac{1}{2}$	50	27·3	30·0	25·4		
$12\frac{3}{4}$	67	27·1	31·4	25·0		
	Average of Quarterly Averages		30·1	25·1		
13	80	28·0	32·4	25·2	333	28·0
$13\frac{1}{4}$	77	28·0	34·2	24·0		
$13\frac{1}{2}$	96	28·2	32·4	25·0		
$13\frac{3}{4}$	80	27·9	31·4	24·6		
	Average of Quarterly Averages		32·3	24·7		
14	110	27·0	37·0	25·2	367	28·3
$14\frac{1}{4}$	79	28·7	34·0	25·0		
$14\frac{1}{2}$	97	28·1	34·4	25·4		
$14\frac{3}{4}$	81	29·4	35·1	25·4		
	Average of Quarterly Averages		35·1	25·2		

TABLE XXII.—STATEMENT OF THE CHEST-GIRTH, &C.—*continued.*

Age in Quarters of years	No. of Observations	Chest-girth in Inches and Decimals				
		Quarterly			Yearly	
		Average	Maximum	Minimum	No. of Observations	Average
15	85	30·2	33·4	26·0	315	30·3
$15\frac{1}{4}$	78	30·1	35·4	26·2		
$15\frac{1}{2}$	69	30·4	36·0	26·4		
$15\frac{3}{4}$	83	30·7	35·4	27·0		
	Average of Quarterly Averages		35·0	26·4		
16	77	32·2	34·2	26·6	283	32·0
$16\frac{1}{4}$	75	31·7	36·0	28·0		
$16\frac{1}{2}$	73	31·9	38·0	27·0		
$16\frac{3}{4}$	58	32·2	38·0	27·0		
	Average of Quarterly Averages		36·5	27·1		
17	46	32·3	36·0	28·6	148	32·3
$17\frac{1}{4}$	46	32·0	36·0	27·2		
$17\frac{1}{2}$	26	32·4	35·1	30·0		
$17\frac{3}{4}$	30	32·5	36·6	29·0		
	Average of Quarterly Averages		35·9	28·7		
18	27	32·8	35·4	29·6	59	34·0
$18\frac{1}{4}$	16	34·0	37·0	30·4		
$18\frac{1}{2}$	9	34·5	40·0	33·0		
$18\frac{3}{4}$	7	33·5	36·0	30·4		
	Average of Quarterly Averages		37·1	30·8		
19	9	33·2	35·4	31·0	20	32·9
$19\frac{1}{4}$	5	32·7	33·4	32·0		
$19\frac{1}{2}$	5	32·7	33·4	32·2		
$19\frac{3}{4}$	1	33·0	—	—		
	Average of Quarterly Averages		33·8	31·6		
20	2	29·7	31·4	28·0	2	29·7

TABLE XXIII.—Abstract of the HEIGHT, WEIGHT, and CHEST-GIRTH of the Boys in Marlborough College, observed at each year of age, with the actual and proportional rate of annual increase.

Age	Number of Observations	Average	Maximum	Minimum	Average of Quarterly Maxima	Average of Quarterly Minima	Annual Increase in Inches	Percentage Proportion of Increase at each age
	Height in Inches and Decimals							
From 9 to 10	6	53·7	57·2	51·0	55·6	54·2	—	—
10 ,, 11	25	54·4	57·6	49·4	56·6	51·6	0·7	1·30
11 ,, 12	84	56·0	67·0	48·2	62·4	50·2	1·6	2·94
12 ,, 13	208	57·3	70·0	52·0	64·4	52·6	1·3	2·27
13 ,, 14	333	58·7	71·2	49·6	68·0	52·5	1·5	2·62
14 ,, 15	367	61·4	69·0	51·2	68·3	53·7	2·7	4·60
15 ,, 16	315	63·4	73·5	54·0	70·6	55·3	2·0	3·25
16 ,, 17	283	65·6	72·2	54·6	71·3	58·8	2·2	3·35
17 ,, 18	148	67·5	76·4	57·4	73·3	60·7	2·0	3·07
18 ,, 19	59	68·5	72·4	63·4	71·2	64·0	1·0	1·48
19 ,, 20	20	67·4	73·4	63·0	69·3	63·5	Decrease 1·1	Decrease 1·60
20	2	62·7	67·0	58·4	—	—	—	—
Total. .	1850							
	Weight in lbs. and Decimals							
From 9 to 10	6	77·0	82·0	74·0	80·5	74·5	—	—
10 ,, 11	25	73·3	91·0	63·0	82·5	65·7	Decrease 3·7	− 5·05
11 ,, 12	84	79·4	104·0	56·0	98·0	63·7	+ 0·9	+ 1·14
12 ,, 13	208	84·7	115·0	58·0	108·7	63·5	+ 5·3	+ 6·67
13 ,, 14	333	92·3	144·0	58·0	132·2	66·5	+ 7·6	+ 8·99
14 ,, 15	367	101·5	163·0	64·0	147·5	72·0	+ 9·2	+ 9·96
15 ,, 16	315	113·2	186·0	73·0	161·7	79·2	+ 11·7	+11·50
16 ,, 17	283	127·0	179·0	76·0	171·7	88·7	+ 14·0	+12·36
17 ,, 18	148	136·3	201·0	94·0	178·2	102·7	+ 9·3	+ 7·32
18 ,, 19	59	144·1	210·0	104·0	176·0	120·7	+ 7·8	+ 5·72
19 ,, 20	20	140·0	160·0	121·0	151·0	127·0	Decrease 6·1	Decrease 2·77
20	2	116·0	139·0	93·0	139·0	93·0	Exceptional	—
Total. .	1850							
	Chest-girth in Inches and Decimals.							
From 9 to 10	6	27·4	29·0	26·0	27·8	26·1	—	—
10 ,, 11	25	26·1	28·2	21·2	27·3	24·1	− 1·3	− 4·74
11 ,, 12	84	27·0	31·0	21·4	30·0	24·1	+ 0·9	+ 3·44
12 ,, 13	208	27·0	31·4	21·4	30·1	25·1	+ —	+ nil
13 ,, 14	333	28·0	34·2	24·0	32·3	24·7	+ 1·0	+ 3·70
14 ,, 15	367	28·3	37·0	25·0	35·1	25·2	+ 0·3	+ 9·10
15 ,, 16	315	30·3	36·0	26·0	35·0	26·4	+ 2·0	+ 7·06
16 ,, 17	283	32·0	38·0	26·6	36·5	27·1	+ 1·7	+ 5·61
17 ,, 18	148	32·3	36·6	27·2	35·9	28·7	+ 0·3	+ 0·09
18 ,, 19	59	34·0	40·0	29·6	37·1	30·8	+ 1·7	+ 5·26
19 ,, 20	20	32·9	35·4	31·0	33·8	31·6	− 1·1	− 3·23
20	2	29·7	31·4	28·0	31·4	28·0	Exceptional	—
Total. .	1850							

TABLE XXIV.—HEAD-GIRTH of Boys at Marlborough College. 'Measured on a line passing above the occipital protuberances and above the frontal eminence.'

Head-girth in Inches	Age last Birthday										
	9	10	11	12	13	14	15	16	17	18	19
24·5	—	—	—	—	—	—	—	1	—	—	—
24	—	—	—	—	—	—	—	—	2	—	—
23·5	—	—	—	—	—	1	2	3	2	2	—
23	—	—	—	—	1	2	6	8	14	7	2
22·5	—	—	—	4	14	29	44	63	42	22	10
22	1	1	3	20	60	60	94	84	45	14	8
21·5	3	4	13	65	124	137	106	81	30	12	2
21	—	12	23	85	85	91	52	36	15	3	—
20·5	—	7	31	34	43	39	16	6	—	1	—
20	—	2	17	10	6	10	2	2	—	—	—
19·5	—	—	2	1	—	1	—	—	—	—	—
Total Observations	4	26	89	219	333	370	320	282	150	61	22
Average Head-girth	21·62	20·96	21·03	21·23	21·44	21·48	21·77	21·95	22·18	22·23	22·36

NOTE.—The Committee recommend that the head-girth should be taken on a line passing just above the frontal eminence (or eyebrows), including the occipital protuberance. This and all other girths should be taken with a plain tape, and the length afterwards read off on a rule, divided into inches and tenths of inches.

TABLE XXV.—ARM-GIRTH of Boys at Marlborough College. 'The arm was held in a loosely-flexed state, the muscles being at rest and flaccid; the measurement being made round the thickest part of the biceps muscle.'

Arm-girth in Inches	Age last Birthday										
	9	10	11	12	13	14	15	16	17	18	19
13	—	—	—	—	—	—	—	—	—	1	—
12·5	—	—	—	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	3	2	2	2
11·5	—	—	—	—	—	—	1	4	3	6	1
11	—	—	—	—	—	5	6	17	11	5	2
10·5	—	—	—	—	2	2	4	24	24	13	1
10	—	—	—	1	1	13	39	47	45	16	9
9·5	—	—	—	1	12	23	43	71	28	10	4
9	—	—	4	11	34	76	74	66	21	7	3
8·5	—	1	11	33	75	87	86	30	12	1	—
8	2	3	22	70	114	107	50	15	4	—	—
7·5	1	12	31	71	79	48	12	4	—	—	—
7	1	9	17	28	15	8	5	1	—	—	—
6·5	—	1	3	4	1	—	—	—	—	—	—
6	—	—	1	—	—	—	—	—	—	—	—
Total Observations	4	26	89	219	333	370	320	282	150	61	22
Average Arm-girth	7·50	7·26	7·55	7·71	8·01	8·34	8·76	9·36	9·70	10·12	10·04

NOTE.—The arm-girth should be taken when the arm is extended horizontally at the thickest part of the biceps muscle. In right-handed persons the right arm, and in left-handed persons the left arm, should be measured.

TABLE XXVI.—LEG-GIRTH of Boys at Marlborough College. 'Measured at the thickest part of the calf, the muscles being at rest.'

Leg-girth in Inches	Age last Birthday										
	9	10	11	12	13	14	15	16	17	18	19
16·5	—	—	—	—	—	—	—	—	1	1	—
16	—	—	—	—	—	—	—	1	—	1	—
15·5	—	—	—	—	—	—	1	2	1	—	—
15	—	—	—	—	—	1	4	5	5	5	1
14·5	—	—	—	—	1	2	7	19	15	7	3
14	—	—	—	—	1	10	28	35	27	20	8
13·5	—	—	—	—	8	27	38	49	37	13	5
13	—	—	1	8	23	53	76	89	38	10	2
12·5	—	—	5	15	37	54	59	42	10	4	2
12	—	2	7	43	78	109	58	27	12	—	1
11·5	1	4	16	52	95	68	35	9	3	—	—
11	1	8	34	68	62	32	10	2	1	—	—
10·5	1	5	18	19	23	9	3	1	—	—	—
10	1	6	7	12	4	5	1	—	—	—	—
9·5	—	1	—	2	1	—	—	—	—	—	—
9	—	—	1	—	—	—	—	—	—	—	—
Total Observations	4	26	89	219	333	370	320	282	150	61	22
Average Leg-girth	10·75	10·70	11·00	11·31	11·63	12·09	12·62	12·99	13·32	13·90	13·61

NOTE.—The leg-girth should be taken in the standing position at the thickest part of the calf. The right leg in right-legged persons, and the left leg in left-legged persons, should be measured.

VII. *Telegraph Messengers.*

Mr. G. Carrick Steet has published, in the 'St. George's Hospital Reports' (1874–6), a paper on the development and growth of boys between 13 and 20 years of age, from which Table XXVII. is extracted.

This table shows the average weight, chest-girth, and *lifting* strength of boys of the same stature, but of different ages, and elicits the interesting fact that there is, with increasing age, an increase in the weight, girth, and strength, even when the height remains stationary. Mr. Steet constructed the table to form standards of the average physical proportions of candidates for the postal, telegraph, and similar branches of the Civil Service throughout the country—a purpose for which they are well fitted. The figures in black type indicate the stature of the boys which should be selected.

VIII. *Females.*

Hitherto the Committee has been engaged in obtaining statistics relating only to males, but they have received from Mrs. Bovell-Sturge, M.D. (Paris), observations on 100 girls, by the consent and co-operation of Miss Buss, of the North London Collegiate School. These will be dealt with in future reports.

TABLE XXVII.—Ages, Weight, Chest-circumference, and Strength of 3,695 accepted and rejected candidates for employment in the service of the Telegraph Department.

Height in Inches	Examined							Average Weight in lbs.						
	Ages							Ages						
	13	14	15	16	17	18	19	13	14	15	16	17	18	19
51	1	—	—	—	—	—	—	62	—	—	—	—	—	—
52	1	1	—	2	—	—	—	73	70	—	67	—	—	—
53	9	4	—	—	—	—	—	72	69	—	—	—	—	—
54	**64**	42	5	1	—	—	—	74	74	74	67	—	—	—
55	**120**	**125**	18	3	—	2	—	75	76	77	76	—	76	—
56	**102**	**185**	35	9	2	—	—	78	80	78	87	81	—	—
57	**115**	**170**	**48**	30	—	—	—	82	83	83	86	—	—	—
58	**57**	**131**	**46**	47	5	—	—	86	86	87	88	94	—	—
59	47	**89**	**85**	62	13	1	—	87	89	91	93	93	91	—
60	18	87	**81**	**82**	6	2	—	90	93	92	96	101	109	—
61	8	34	**76**	**115**	37	3	4	96	98	99	101	106	102	119
62	4	22	66	**116**	**55**	12	4	96	101	104	106	109	111	113
63	1	29	57	**146**	**77**	**24**	**9**	103	108	108	110	115	117	117
64	3	18	37	**117**	**82**	**28**	**15**	111	112	115	115	116	115	120
65	—	3	26	72	**69**	**21**	**21**	—	107	117	115	120	127	121
66	—	4	8	43	**48**	**27**	**14**	—	119	117	122	126	126	130
67	—	1	7	29	26	**12**	**11**	—	123	120	125	132	129	138
68	—	—	6	10	18	11	8	—	—	131	126	131	142	144
69	—	1	3	9	7	5	6	—	129	143	132	138	144	140
70	—	—	1	2	3	4	2	—	—	136	144	147	151	137
71	—	—	—	—	1	1	3	—	—	—	—	149	129	150
Number Examined at each Age	550	946	605	895	449	153	97							
Average Height in Inches at each Age	56·5	57·6	60·4	62·2	63·9	64·8	65·5							

Height in Inches	Average Chest-circumference							Average strength in lbs. (lifting)						
	Ages							Ages						
	13	14	15	16	17	18	19	13	14	15	16	17	18	19
51	23	—	—	—	—	—	—	168	—	—	—	—	—	—
52	24	24·5	—	24·62	—	—	—	161	224	—	168	—	—	—
53	24·36	23·75	—	—	—	—	—	170	135	—	—	—	—	—
54	24·45	24·73	24·55	22·5	—	—	—	178	183	177	196	—	—	—
55	24·48	24·74	25·27	26	—	25·5	—	175	188	194	203	—	231	—
56	24·67	25	25·06	26·89	24·62	—	—	181	191	196	226	220	—	—
57	25·13	25·46	25·78	26·40	—	—	—	190	196	207	228	—	—	—
58	25·48	25·72	26·12	26·76	27·55	—	—	193	202	197	217	232	—	—
59	25·82	26·16	26·48	27·14	27·7	26·5	—	195	208	212	256	257	252	—
60	25·8	26·62	26·95	27·56	28·25	30·25	—	206	216	223	255	242	322	—
61	26·43	26·95	27·37	28·09	28·49	28	29·5	211	230	238	262	286	261	335
62	26·22	26·56	27·92	28·20	28·61	28·8	29·31	227	237	248	276	284	241	312
63	26·5	27·95	28·17	28·54	29·28	29·5	29·58	238	257	261	279	304	296	304
64	27·33	28·54	28·70	29·1	29·53	29·9	30·02	222	266	262	288	308	333	310
65	—	27·83	29·15	29·14	29·68	30·43	30·05	—	230	284	296	311	316	308
66	—	29·5	29·43	29·73	29·97	30·26	30·41	—	262	248	306	315	322	329
67	—	29	29·89	30·78	31·16	30·12	31·05	—	240	293	330	326	334	343
68	—	—	29·66	31·57	30·01	30·07	31·22	—	—	320	296	314	314	367
69	—	29	31	30·36	31	31·9	31·71	—	280	331	352	354	359	353
70	—	—	29·5	31·37	31·41	32·19	29·25	—	—	322	301	322	359	362
71	—	—	—	—	31	29·75	30·92	—	—	—	—	399	294	420

IX. *Extensions of the Inquiry.*

It has been urged upon the Committee by Major-General A. L. Fox Pitt-Rivers that they ought not to neglect any of the more important measurements used by anthropologists, the utility of which is well established. 'The facts which it is the object of the Committee to deduce concern the influence on race; first, of heredity, and, secondly, of external causes. Anthropometry may be divided under the three heads: size, form, and colour. Of these, the Committee have as yet taken cognizance only of size and colour, except so far as the collection of photographs may be regarded as bearing on form; but as the study of physiognomy is not yet reduced to a system, no statistics can be derived from these. Of the three headings, size, form, and colour, as tests of race, colour is generally allowed by anthropologists to be the most important because the most persistent, form the next, and size the least important, because all animals are able to increase in bulk through good living, whereas this cause has less influence on colour and form. Of the various measurements relating to form, head form, especially the cephalic index, seems the most important, for the following reasons:—it is universally employed, easily obtained, ample data for comparison already exist, it can be obtained from living subjects as well as skulls, it is useful not only as a test of race, but also in its bearing upon intellect.' General Pitt-Rivers therefore proposed that the greatest length and greatest breadth of head should be added to the subjects inquired for by the Committee. The Committee propose that this should be done in future years.

The Committee have had before them also a paper by Dr. Mahomed relating to useful extensions of the inquiry to medical subjects in cases where the observers are duly qualified medical men. Upon these suggestions they propose also to act hereafter.

X. *Photographs.*

The collection for publication of photographs of the typical races of the Empire has been again entrusted to a sub-Committee, of which Mr. Park Harrison has been so good as to act as convener. Their report, prepared by him, is subjoined.

'During the past year about 400 photographs have been received by the Committee, mostly from Wales, the Shetland Isles, Morayshire, North and South Arran, Cornwall, East Norfolk, Worcestershire, and the more remote parts of Kent and Sussex. A certain number have been arranged on sheets of cardboard for more ready comparison.

'The photographs from Shetland, taken in full face and profile for the Committee at the expense of Mr. Bruce, the owner of Unst Island, are of considerable value. They comprise the portraits of fourteen individuals belonging to families who have inhabited the islands as long as there are any records; and they still, in several cases, retain their original Scandinavian names.

'The portraits from Moray and Arran, with others from different parts of Scotland, were presented by Dr. Muirhead.

'The Welsh photographs, obtained by Mr. Harrison, represent the darker race in the Principality, and assist in the recognition of kindred types which appear to exist, with more or less mixture, in various districts in England; for example, at Brandon, in Norfolk. Several portraits

from that locality have been mistaken by competent judges of physiognomy for Welsh. The inhabitants contrast strongly in colour of hair and eyes with the population of other parts of the county.[1]

'In several other counties there appear to be populations differing essentially in features; but a larger number of portraits, taken on a uniform system, in profile and full face, would be required, together with head-measurements, to enable the Committee to define racial characteristics.

'The Committee have been furnished with a fine series of photographs of eleven typical inhabitants of the district around Bradford, Yorkshire, taken and presented by Messrs. Appleton & Co., photographers, of Bradford, and selected and described by Mr. Thomas Tate, F.G.S., to whom the Committee are much indebted.

'Owing to the funds at the disposal of the Committee being required for the reduction of the mass of observations that have been acquired, no other original photographs have been taken this year under their direction. Few consequently of those that have been obtained are of value for strict scientific examination; and by far the greater part of England, and Scotland, and the whole of Ireland, the Channel Islands, and the Isle of Man are unrepresented at present by any photographs.' [2]

The Committee would therefore press on the consideration of the Committee of Recommendations the advisability of an extra grant for the acquisition of photographs.

XI. *Conclusion.*

The Committee request that they may be reappointed, and suggest that the reference should be in the more general terms 'for the purpose of continuing the collection of anthropometric observations and of photographs of the typical races of the Empire.'

They have received most efficient services in abstracting the returns and otherwise from their assistant secretary, Mr. J. Henry Young.

Report of the Committee, consisting of Dr. PYE-SMITH, Professor M. FOSTER, *and* Professor BURDON SANDERSON (*Secretary*), *appointed for the purpose of investigating the Influence of Bodily Exercise on the Elimination of Nitrogen* (*the experiments conducted by* Mr. NORTH).

DURING the past year four series of preliminary experiments, each of several weeks' duration, have been made by the Committee on the subject, the expenses of which have been met from other funds. In the course of these experiments unexpected difficulties have been encountered relating to method. The most serious of these difficulties having now been for the most part overcome, we are in a position to proceed with our inquiries next winter, and have therefore to request that the sum of 50*l.*, previously granted to us, may again be placed at our disposal.

[1] Out of eighty recruits who joined the West Norfolk Militia this spring, there were only three with black or very dark hair and eyes.

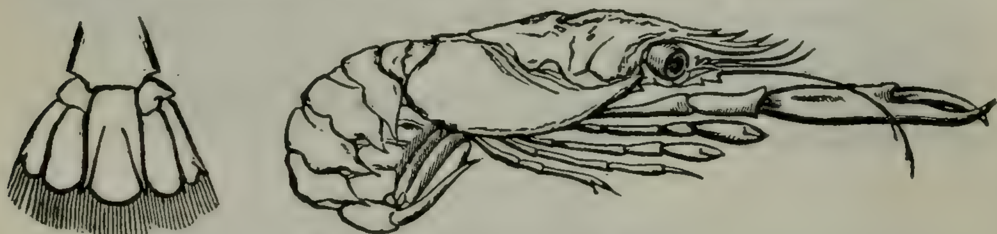
[2] Since the last meeting of the sub-committee several portraits of natives of Heligoland have been received as a gift from the divisional officer of the Coast Guard connected with the island.

Second Report of the Committee, consisting of Mr. C. SPENCE BATE *and* Mr. J. BROOKING ROWE, *appointed for the purpose of exploring the Marine Zoology of South Devon.*

WE beg to report that we have had a series of dredgings, &c., from various parts of the coast of Devon and Cornwall, selecting more especially those localities that have been hitherto little explored, or which previous research has shown to be places of interest for the objects that have been found.

From off the Dudman we have received many animals, which, although not new, yet have been considered as being among the rarer of our British Crustacea. Among them are *Polybius henslowii*, and a macrura that is new to the coast, if not an undescribed species. It evidently belongs to the genus *Nephropsis*. *Nephropsis stewarti* was taken by Mr. Wood-Mason in the Indian Seas at a depth of 300 fathoms; another species has been taken during the *Challenger* Expedition at 700 fathoms, south of New Guinea; and another at 800, from off Bermuda: *N. Atlantic.* All these are remarkable for the depth at which they were taken, as well as for the rudimentary or depauperised condition of the eye-stalks; whereas the British form was taken floating on the surface of the sea, and has large and well-developed eyes.

The resemblance of all four species is very close, and the distinction of one from the other is dependent chiefly upon the modified forms of more or less important parts.



Nephropsis cornubiensis (new species).

We look upon the discovery with considerable interest, as it bears a near resemblance to the preserved fossil remains of *Hoploparia belli*, as figured by Woodward in his table of fossil Crustacea.

If we compare our newly-found form with *Nephrops norvegicus* of the Northern Ocean, we shall find many points of similarity and many also of definite separation—the latter so strong that were we assured that *Nephropsis cornubiensis*, the name by which we provisionally intend to recognise the newly-found species, were an adult or mature form, we should not hesitate to accept it as a distinct species. But as we know so little of the young of any of the macrura after they have passed the earliest forms in which they first appear, we are induced to believe it may be no other than an immature condition of *Nephrops*. If this be the case then all the species of the genus *Nephropsis* (Wood-Mason) must be recognised as in the same position, and probably the fossil *Hoploparia* also. There are conditions that make one hesitate to affirm this too hastily, and among these are the facts that, in the localities where *Nephropsis* has been taken, *Nephrops* has not been recorded. There has been no instance of *Nephrops* having been taken in the English Channel, or anywhere south of the

North-Irish and Scotch waters. And as far as we are aware, no specimen of the genus has been taken in New Guinea, the Philippine Islands, or Bermuda.

This is, however, but negative evidence, and only valuable until research has been perfected; and until it is more so than at present, it will be convenient to allow the genus *Nephropsis* to include the smaller forms.

We have also obtained specimens of *Arctus arctus*, and many others of interest. But the sudden and severe illness of our colleague Mr. J. Brooking Rowe, on whose assistance we had calculated, has precluded us from a complete examination of all our specimens, more especially in Annelids, Mollusca, &c. A box of offshore washings has been placed in the hands of Dr. Zenker, of Potsdam, for examination, more especially to ascertain the entomostracous forms of Crustacea that may exist in this locality.

When all liabilities have been paid, we expect to have some eight or nine pounds still in our possession, with which we hope to be able to complete our report at the next meeting of the Association.

The collections that we may secure we propose to deposit in the museum of the Athenæum at Plymouth, which is essentially of a local character, and the duplicates, more especially the edriophthalmous species of Crustacea, we intend forwarding to the Bristol Museum, to perfect the collection of British forms in that institution.

Report of the Committee, consisting of Dr. M. FOSTER, Professor ROLLESTON, Mr. DEW-SMITH, Professor HUXLEY, Dr. CARPENTER, Dr. GWYN JEFFREYS, Mr. SCLATER, Mr. F. M. BALFOUR, Sir C. WYVILLE THOMSON, Professor RAY LANKESTER, *and* Mr. PERCY SLADEN (*Secretary*), *appointed for the purpose of arranging for the occupation of a Table at the Zoological Station at Naples.*

YOUR Committee have to report that the Zoological Station at Naples continues in a most satisfactory state. Under the able management of Dr. Dohrn, no opportunity is left unemployed for promoting its efficiency and utility; and in these endeavours he is admirably seconded by his whole staff. During the past year the establishment has been placed upon a more secure footing than it has previously enjoyed, by the German Government having voted a grant equivalent to 1500*l.* towards the support of the Station, and which is understood to be an annual and permanent one. As a proof of the great interest taken in the undertaking in Germany, it may be mentioned that this grant was the result of a direct resolution of Parliament on a petition moved by Helmholtz, Dubois-Raymond, and Virchow; and that in the discussion that followed many of the chief men of the Reichstag took part. The money is bestowed as a donation from the Empire, for which no return is asked, each separate State paying for the hire of its table in the usual way; Prussia having three tables, and five other States one each. In addition to this Prussia votes 150*l.* annually towards the publications of the Station; and the Berlin Academy has this year granted 100*l.* for the first

volume of the 'Fauna und Flora.' It will thus be seen that Germany contributes a total sum of between 2250*l.* and 2350*l.* per annum towards the expenses of the undertaking: a truly noble support, when it is borne in mind that the nation has no greater direct participation in the advantages of the Station than any other country or association that may hire a table.

In addition to the tables previously taken, one has recently been hired by Belgium and one by the Italian Navy; the last chiefly for the purpose of instructing officers in the collection and preservation of marine organisms. Russia has also prolonged its contract for five years.

The Royal Society has granted 100*l.* towards the publications.

Respecting the publications issued under the auspices of the Station, the following monographs of the series 'Fauna und Flora des Golfes von Neapel' will be issued in the course of a few weeks:—

1. Dr. Chun: 'Ctenophora.'
2. Dr. Emery: 'On Fieresfer.'

The remaining monographs mentioned in the previous Report are all in a forward state; and to the list already given there has recently been added one by Dr. Andres on the Actiniæ of the Gulf.

Of the 'Mittheilungen aus der Zoologischen Station' (in which are published, amongst other works, the investigations carried out by the members of the staff of the Station which are not comprised in special monographs) vol. i. and vol. ii. part i. have already appeared, and part ii. is now in the press.

The 'Prodromus Faunæ Mediterraneæ' is near completion, and may probably appear during the year.

The 'Zoologischer Jahresbericht' for 1879 is in the press.

The Library of the Station is continually on the increase, and the number of journals has been considerably augmented by the exchange of the 'Mittheilungen' for the proceedings published by other institutions.

The collecting capabilities of the Station have gained an important advantage in the Scaphander diving-apparatus. Officials belonging to the establishment have already descended to a depth of 20 mètres, and remained over an hour on the sea-floor, searching for animals and plants; and by this method many new insights have been obtained.

A new tow-net has also been constructed, according to a device of Dr. Dohrn's, by which the animals occurring in different depths may be caught; the apparatus being so arranged that the net can be opened or closed at any depth it may be desired to investigate.

Surface-collecting is carried out daily as usual; and dredging from the steamer is prosecuted several times per week; excursions for this purpose having latterly been extended as far as Gaeta and the Ponza Islands.

In order to keep pace with the advances made in methods of investigation, various additions of apparatus and instruments have been acquired by the laboratory: under this category may be mentioned four new microtomes, a micro-polariscope, a spectroscope, and an induction apparatus, besides other apparatus which it is unnecessary to mention here.

Two elevated reservoirs have recently been erected, by which a regular circulation of sea-water can be supplied to a number of smaller basins, specially constructed as working laboratory tanks.

By means of the reconstructions carried out during the previous year

the aquarium has gained both in beauty and utility, whilst the new system upon which the glass plates have been fixed has proved so satisfactory that not a single leakage has taken place. Observations upon the organisms *in situ* are much facilitated, being now taken regularly, and tabulated by one of the officials of the Station.

In the Dredging Department the Station has received from Dr. Wm. Siemens about 1000 mètres of iron wire of special manufacture, wherewith dredging can be carried on in much greater depths than formerly.

Your Committee have pleasure in announcing that since the presentation of their last Report, Dr. Dohrn has himself set on foot a scheme for the foundation of a travelling fund for the benefit of naturalists who may occupy the English tables, and that a sum of money has been contributed which may be applied to this purpose. Your Committee are therefore now in a position to offer a grant of money towards the travelling expenses of any naturalist who may be selected to occupy the Association table.

It should also be mentioned that preparations are progressing for the establishment of a small Zoological Station at Messina, as a dependency of the one at Naples. Students who come to work at the latter place will thus be enabled to find similar advantages at Messina, although on a smaller scale; whilst the fauna is even richer in pelagic animals than that of Naples.

For these additional advantages, several lessors of tables (Prussia, Baden, Strasburg, and others) have already consented to raise their contributions from 75*l.* to 90*l.* Your Committee would strongly advocate the adoption of a similar course by the Council of the British Association; not only on this account, but also in recognition of the special advantages afforded to occupiers of the English tables by the establishment of the travelling fund above mentioned.

Your Committee would, with these particulars before them, most strongly urge the renewal of the grant as a worthy contribution towards the advancement of science.

Since the last Report the Association table has been occupied by Mr. Arthur Wm. Waters, whose report will be found appended; and also various details, kindly furnished by the staff of the Zoological Station.

I. *Report on the Occupation of the Table, by Mr. Arthur Wm. Waters.*

The British Association granted me the use of their table at the Naples Zoological Station for two months, from the beginning of November last year; but, being in an unsatisfactory state of health, I soon found that I was unable to stand the climate of Naples, and was forced to leave by the middle of that month, and, consequently, have no report to furnish of work completed, but will indicate some of the points I hoped to be able to investigate.

Recently a good deal of attention has been paid to a tissue of the Bryozoa, now called the endosarc, which at one time was looked upon as a colonial nervous system; but, thanks to the researches of Joliet and others, we are able to see that the earlier views were quite incorrect, and know that it plays a most important part in the economy of the colony, although not as a nervous system, but in connection with the growth and life of the various parts of the Bryozoon. The endosarc in one zooecium

is connected with that in another by means of disks in the zooecial walls,[1] which have been called rosette-plates.

These rosette-plates I found, as regards position, form, &c., furnish characters which in some genera are of great use in the specific determination, and from what I have seen anticipate that in some cases they also can be used to distinguish genera. By the position of the rosette-plates in recent and fossil species (when the state of fossilization allows examination), the part of the zooarium from which fresh growth takes place is in most cases clearly indicated; and it seemed to me of great importance that a comparative study of the endosarc and its position, and of the rosette-plates, should be made; and the arrangements of the Zoological Station furnish every opportunity for so doing, and made it the more disappointing to relinquish the investigation.

Zoobotryon pellucidus, the ctenostomatous species examined by Reichert, being transparent, is very favourable for examination, and from watching it in different circumstances I conclude that in the normal condition the endosarc always consists of a large number of fine threads, and when it is found as a more solid cord it is in a less vigorous state, absorption of some of the tissues has commenced, and, if I am justified in drawing conclusions from incompleted work, this condition must be looked upon as pathological, or, perhaps, it must be considered the result of a check to growth caused by periodical or exceptional causes, such as the unsatisfactory nature of life in an aquarium. This was shown in several cases in specimens which, when freshly collected, showed a vast number of anastomosing threads, but after living some days in the aquarium presented the thick cord in much the condition figured by Reichert.

After some considerable trouble I induced *Diachoris magellanica*, a transparent cheilostomatous species, to root upon some slips of glass, placed in my small tank for the purpose; but being successful in this only just before leaving, I was unable to make the continuous observations intended. It, however, seemed that while this species, which is brought from a depth of 30 to 40 fathoms, would live in the aquarium, showing for some time activity of the avicularia, and occasionally movement of the polypide, and also throwing out radicles, there was, with this exception, no further growth; so that a bud, which was growing when brought in, would remain at the same stage, and the contents of the cell, which were of a cellular character, would separate into an irregular network.

From these and other observations, I saw reason to believe that besides the study of actively growing specimens, much could be learnt from an examination of the reversed changes, which take place when growth is arrested; and apparently arrest of growth takes place in some parts frequently and perhaps in the whole periodically, when the endosarc will become consolidated, and is thus a store ready for fresh growth.

From the immediate neighbourhood, I found but few species not mentioned in the paper published two years ago, but hope shortly to draw up a list of additions from a somewhat wider range; some are species known in distant localities, thus again showing that the geographical range is often very large with the Bryozoa.

[1] The rosette-plates may be seen also in the diaphragms of some Ctenostomata; in the avicularian chambers, and in *Membranipora cervicornis* is well developed at the base of the projecting process.

Of material, which I had more or less prepared for examination, I sent home a series in tubes and bottles at that time, hoping I should in the future have the health to complete the investigation, but if unable to do so, these points will no doubt all be elucidated ere long by others.

I found the zoological station much changed in several particulars since I was previously there. The staff is now much larger, with the duties more subdivided; and the library, which is now removed into a more convenient room, is much improved; but for some time the weak point is likely to be in systematic works. I cannot close without saying that I always found the staff ready to give me every assistance, and must thank Dr. Dohrn and Dr. Eisig for their kindness, especially in giving me leave to apply to the Station for help in any work I undertook while remaining in the neighbourhood.

II. *Report on the Reference Collection.*

The General Reference Collection has latterly received considerable attention under the management of Dr. Paul Mayer (in conjunction with Mr. Schmidtlein for Fauna and Distribution, and Dr. Berthold for Botany). Dr. Mayer has kindly furnished the following notes.

1. The object of collection is:—
   a. To facilitate the determination of specimens for students working in the laboratory, and to serve as a reference in doubtful cases.
   b. To collect material for the Fauna of the Gulf of Naples (extending northward to Gaeta and southward to Salerno), and specially for comparison with the forms from Messina.
   c. To collect material for systematic purposes, such as the investigation of individual variation, mimicry, and biological questions in general.
   d. To obtain material for anatomical and special histological investigations, special reference being had to the best methods of preservation.
2. Preservation is generally effected in alcohol of 70 to 90 %; for fishes, alcohol of 50 % is mostly used; and plants are usually placed first in concentrated solution of common salt, and then in alcohol.
3. The number of specimens representing the different groups of animals varies greatly, because (*a*) some of the forms are not equally abundant in all localities; (*b*) the preservation is not yet sufficiently good in many groups for the animals to remain thoroughly recognizable; (*c*) in many groups the determination cannot at present be carried out.
4. The determination of the specimens is undertaken, as far as practicable, by specialists.
5. The following summary will indicate the present condition of the different groups:—
   a. *Fishes.*—Most of the forms of the Gulf represented, together with some interesting young stages.
   b. *Tunicata.*—Well represented, specially Ascidiæ; and nearly all determined.

III. A List of the Naturalists who have worked at the Station from the end of July, 1879, to the end of June, 1880.

Number on List	Naturalist's Name	State or University whose Table was made use of	Duration of Occupancy		Publications which have resulted, up to the present time, from the Investigations undertaken at the Station	Where published
			Arrival	Departure		
125	Dr. Ewald	Baden	Aug. 28, 1879	Oct. 30, 1879		
126	Dr. Brandt	Berlin Academy	Sept. 9 ,,	Dec. 21 ,,		
127	Prof. Götte	Strasburg	,, 13 ,,	March 1, 1880		
128	Stud. Staigmüller	Würtemberg	,, 24 ,,	April 21 ,,		
129	Dr. Vigelius	Holland	Oct. 3 ,,	Jan. 12 ,,	Voorlopig Verslag van de werkzammheden. (Cephalopoden Anatomie.)	
130	Prof. Du Plessis	Switzerland	,, 13 ,,	April 7 ,,		
131	Mr. Waters	British Association	,, 13 ,,	Dec. 1, 1879		
132	Dr. Brock	Bavaria	,, 17 ,,	March 1, 1880		
133	Prof. Schmitz	Prussia	,, 24 ,,	,, 22 ,,		
134	Dr. Batelli	Italy	Nov. 27 ,,			
135	Prof. Metchnikoff	Russia	Dec. 4 ,,	May 19 ,,	Ueber die intracelluläre verdauung der Coelenteraten	'Zool Anzeiger,' No. 56, 1880
136	Dr. Valiante	Italy	Jan. 1, 1880			
137	Dr. Della Valle	,,	,, 1 ,,			
138	Dr. Andres	,,	,, 1 ,,			
139	Dr. Foettinger	Belgium	Feb. 1 ,,			
140	Dr. Spengel	Hamburg	,, 1 ,,	June 8 ,,		
141	Dr. Spangenberg	Bavaria	,, 14 ,,	April 4 ,,		
142	Cand. Rebmann	Baden	March 20 ,,	,, 5 ,,		
143	Prof. Hofmann	Holland	,, 22 ,,			
144	Dr. Ludwig	Prussia	April 1 ,,	May 19 ,,		
145	Dr. Yung	Switzerland	,, 4 ,,			

c. *Mollusca*.—Gasteropoda and Conchifera determined part by Kobelt and part by Gwyn Jeffreys. The Cephalopoda include some rarities from Messina, but numerous blanks exist in the group, specially in the Nudibranchiata.

d. *Echinodermata*.—Most of those named in Ludwig's 'Prodromus,' and all determined by him.

e. *Crustacea*.—Nearly all the Decapoda recorded by Camill Heller (some of them being new to the Fauna of the Gulf of Naples), determined by P. Mayer. Important collection of Zœæ reared from the egg.

Amphipoda, Isopoda, Copepoda, &c., only poorly represented, on account of the difficulty of determination.

f. *Bryozoa*.—Nearly all collected and determined by A. Waters.

g. *Nemertina*.—Determined by Dr. Hubrecht.

h. *Annelida*.—By Dr. Eisig.

i. The remainder of the *Annulosa* only imperfectly represented, pending the publication of the monograph on the subject.

k. *Cœlenterata*.—Fairly numerous, especially sponges, which are well represented.

l. *Protozoa*.—Just commenced.

IV. A List of Papers which have been published since the Presentation of the previous Report, by the Naturalists mentioned therein.

Dr. v. Ihering . . .	Beiträge zur Kenntniss der Nudibranchien des Mittelmeers. I. ('Malak. Blätter.' N. F. ii.)
„ . .	Graffilla muricicola, eine parasitische Rhabdocoele. ('Zeitsch. wiss. Zool.' Bd. 34.)
Dr. Hubrecht . .	Vorläufige Resultate fortgesetzten Nemertinen-Untersuchungen. ('Zool. Anzeiger,' 1879.)
„ . .	The Genera of European Nemerteans critically revised. ('Notes, Leyden Museum,' 1879.)
„ . .	Vorloopig Overzigt van het Naturhist. Onderzeek, etc. in het Zool. Station de Naples.
„ . .	Zur Anatomie und Physiologie des Nervensystems der Nemertinen. (Amsterdam, 1880.)
Mr. Percy Sladen .	On a remarkable form of Pedicellaria, and the functions performed thereby; together with general observations on the allied forms of this organ in the *Echinidæ*. ('Ann. and Mag. Nat. Hist.' ser. v. vol. vi. 1880.)
Dr. Della Valle .	Sui Coriceidi parassiti, e sul anatomia del gen. Lichomolgus. (Mittheil. Zool. Station, Bd. II.)
Mr. Geddes . .	Sur la Chlorophyle Animale (P.S.). ('Archives Zool. Expérim.' t. 8.)
Dr. Berthold . .	Zur Kenntniss der Siphoneen und Bangiaceen. ('Mittheil. Zool. Station,' Bd. 2.)
Dr. Solger . . .	Neue Untersuch. zur Anatomie der Seitenorgane der Fische. ('Archiv. für Mikr. Anatomie,' Bd. 17.)
Dr. Keller . . .	Studien über Organisation u. Entwickelung der Chalineen. ('Zeitschr. wiss. Zool.' Bd. 33.)
Prof. Selenka . .	Keimblätter und Organanlagen bei Echiniden. ('Zeitschr. wiss. Zool.' Bd. 33.)
Profs. Oscar and Richard Hertwig	Die Actinien anatom. und histol. mit besonderer Berücksichtigung des Nervensystems untersucht. (Jena, 1879.)
Prof. v. Koch . .	Bemerkungen über das Skelet der Korallen. ('Morphol. Jahrbuch,' Bd. 5, 1879.)
Dr. Mereschkowsky:	Sur la Structure de quelques Corallaires. ('Comptes Rendus,' No. 18, 1880.)

Dr. Mereschkowsky: Sur l'Origine et le Dével. de l'Œuf chez la Medusa Encope, etc. ('Comptes Rendus,' No. 17, 1880.)
Prof. Todaro . . Sui primi fenomeni dello sviluppo delle Salpe. (Real. Accad. dei Lincei, 1880.)

V. A List of Naturalists to whom Specimens have been sent from June 25, 1879, to June 21, 1880.

				Lire
1879.	June 25	F. M. Balfour, Cambridge	Echin. and Mollusca	182
	July 29	Anatomical Museum, Oxford	Coelent. and Mollusca	54
	„ 29	Prof. Ganin, Warsaw	All classes	378
	„ 29	P. de Loriol, Chalet des Bois	Asteroidea	30
	„ 29	Prof. F. E. Schulze, Graz.	Sponges	10
	„ 29	Ed. Schunk, Manchester	Murex	21
	„ 29	Prof. E. Selenka, Erlangen	Selachian embryos	42
	„ 29	Prof. Th. Owsjannikow, St. Petersburg	„ „	38
	Aug. 3	W. Kitchin Parker, London	Hippocampus embryos	13
	„ 20	F. M. Balfour, Cambridge	Chimæra, Clavellina	45
	„ 21	Museum, Toronto	All classes	1,065
	„ 22	Prof. Hasse, Breslau	Torpedo embryos	25
	Sept. 8	Zoolog. Institut, Erlangen	Rossia	12
	„ 22	Chr. Vetter, Hamburg	Coelent. Echin. Mollusca	63
	„ 29	Ung. Jos. Polytechnikum, Budapest	Crustacea	78
	Oct. 6	Prof. Lütken, Copenhagen	Cephalopoda and Fishes	74
	„ 6	Science and Art Dept., South Kensington, London	All classes	345
	„ 25	Prof. Maly, Graz	Dolium	7
	„ 25	Prof. Ray-Lankester, London	Hydromedusæ	102
	Nov. 7	G. Cotteau, Auxerre	Asteroidea	54
	„ 7	Prof. Lovén, Stockholm	All classes	328
	„ 8	Prof. Todaro, Rome	Salpæ	17
	Dec. 2	Naturh. Museum, Frauenfeld	All classes	143
	„ 2	Prof. Schmarda, Vienna	Coelent. Annel. Mollusca	135
	„ 15	Zoolog. Comptoir, Bâle	Coelent. and Echinodermata	52
	„ 24	Dr. P. Fraisse, Würzburg	Gasteropoda	5
	„ 24	Naturh. Museum, Hamburg	Coelent. Echin. Annel. Crustacea	200
	„ 24	Zoolog. Institut, Würzburg	Gasteropoda	18
1880.	Jan. 11	J. Madathian, Riesbach	Physalia	5.70
	„ 12	Zoolog. Institut, Heidelberg	Coelent. Echin. Annelida	140
	„ 27	Prof. C. Vogt, Geneva	Coelent. and Mollusca	150
	Feb. 2	S. Brogi, Sienna	Echinodermata	75
	„ 2	Prof. E. Grube, Breslau	Annelid. Crust. and Fishes	64
	„ 20	Chr. Vetter, Hamburg	Coelent. Echin. Annel. Mollusca	103·60
	March 1	Prof. Alex. Goette, Strasburg	Coelent. Crust. and Mollusca	49
	„ 9	Fischerei-Ausstellung, Berlin	All classes	—
	„ 18	Dr. Belloni, Bologna	Nephrops	11
	April 5	Prof. O. Nasse, Halle	Hydromedusa, Sagitta, Cephalop. &c.	10
	„ 6	N. Fenoult & Co., St. Petersburg	All classes	314
	„ 15	Realschule, Kempten	Elementary collection	41
	„ 16	Dr. Eger, Vienna	Different classes	40
	„ 16	Dr. Retzius, Stockholm	Tunicata and Fishes	81
	„ 16	Zoolog. Museum, Charkow	Different classes	174
	„ 27	Naturhist. Museum, Groningen	All classes	255.50
	„ 27	Gymnasium, Reichenberg	Elementary collection	78
	„ 27	Zoolog. Museum, Lausanne	Different classes	162
	„ 30	Museum, Liverpool	Coelenterata	86·60

				Lire
May	6	M. Rebmann, Karlsruhe	Cephalopoda and Fishes	18
„	24	Naturh. Museum, Bremen	All classes	380
„	24	Zoolog. Institut, Erlangen	Mollusca	78
„	24	„ „ Würzburg	Echin. Cephalop. Annel.	148
June	1	Prof. C. v. Siebold, Münich	All classes	381
„	1	Prof. Theil, Hermannstadt	Elementary collection	62
„	21	Prof. Ehlers, Goettingen	All classes	112

VI. A List of Naturalists to whom Microscopic Preparations have been sent from March 6, 1879, to June 5, 1880.

					Lire
1879.	March 6	Mr. Bruker, Constance	2	preparations	1.50
	May 14	Prof. Harting, Utrecht	15	„	20.91
	June 12	Mr. Haddon, Cambridge	17	„	23.10
	„ 20	Prof. Berlin, Amsterdam	37	„	52.78
	July 18	Prof. Cossar Ewart, Aberdeen	50	„	70.00
	Nov. 3	Prof. Emery, Cagliari	17	„	23.80
	Dec. 20	Dr. Brandt, Berlin	8	„	10.90
					202.99
1880.	Feb. 2	Prof. Emery, Cagliari	10	„	14.00
	„ 14	Dr. Brandt, Berlin	3	„	4.00
	„ 16	Prof. Goette, Strasburg	34	„	46.60
	April 23	Mr. Geddes, Edinburgh	36	„	45.35
	May 17	Prof. Metschnikoff, Odessa	20	„	27.00
	„ 7	Prof. Todaro, Rome	14	„	22.00
	„ 18	Dr. Ludwig, Bremen	29	„	39.15
	„ 18	Prof. Du Plessis, Lausanne	5	„	6.60
	„ 20	Zoolog. Institut, Strasburg	80	„	116.00
	June 5	Dr. Spengel, Göttingen	2	„	2.60
					323.30

Report on accessions to our knowledge of the Chiroptera during the past two years (1878–80). *By* G. E. Dobson, *M.A., M.B., &c.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

One of the chief results hoped for from the publication of my natural history of the order Chiroptera,[1] as stated in the preface to that work, was that it would be 'a stimulus to collectors and students to pay more attention to this difficult and obscure group of animals than has been the case hitherto.' How fully this hope has been realised has been abundantly shown, not only by the publication of numerous papers on the subject in various scientific journals, both home and foreign, contrasting remarkably in number and quality, and especially in the number of different writers, with those recorded in any previous period of like duration, but also by the activity which has been displayed by collectors, as evidenced by the contributions received at the different museums, and by the numerous letters received by the writer from almost all parts of the world from those whose interest in the Chiroptera has been at length awakened.

[1] Entitled *Catalogue of the Chiroptera in the Collection of the British Museum.* Published June, 1878.

To enumerate, classify, and correct these contributions; to add some remarks, supply a few omissions, and correct one or two errors since discovered in the work referred to above, is the object of this paper.

I commence by re-defining the suborders into which I have divided the Chiroptera, adding some important characters previously omitted.

Suborder I.—MEGACHIROPTERA.

Crowns of the molar teeth smooth, marked with a longitudinal furrow; bony palate continued behind the last molar, narrowing gradually backwards; trapezium large, deeply grooved for articulation with the trochlear base of the first metacarpal bone; second finger with three phalanges, generally terminating in a claw; sides of the ear-conch united below, forming a complete ring at the base; pyloric extremity of the stomach elongated; spigelian lobe of the liver ill-defined or absent.

Suborder II.—MICROCHIROPTERA.

Crowns of the molar teeth acutely tubercular, marked with transverse furrows;[1] bony palate narrowing abruptly, not continued laterally behind the last molar; trapezium small, forming a simple articulation with the concave base of the first metacarpal bone; second finger with a single rudimentary phalanx, rarely (in *Rhinopoma* only) with two, not terminating in a claw; stomach simple or with the cardiac extremity more or less elongated; spigelian lobe of the liver well developed.

Suborder I.—MEGACHIROPTERA.

Family—Pteropodidæ.

Epomophorus monstrosus, Allen.[2]

In the Paris Museum I found a specimen of this species from Ogoné, collected by M. Marche, which had previously been unknown south of the equator.

Epomophorus minor.

Epomophorus minor, Dobson, 'P.Z.S.' 1879, p. 715.

This small species should come next after *E. macrocephalus*, which stands second in the list of species in the 'Catal. Chiropt. Br. Mus.' It is scarcely more than half the size of that species, but resembles it in the form and arrangement of the palate ridges. The head is, however, proportionally much shorter and broader, and in comparative measurements the female differs less from the male, as I have shown in the original description. These remarks are founded on an examination of five well-preserved adult specimens which I owe to the kindness of Dr. Robb, H.M. Indian Army, Civil Surgeon of Zanzibar, and the following are the measurements of the largest, a perfectly adult male:—

Length: head and body 4″·0 inches, head 1″·65 (in adult female 1″·55); eye from tip of nostril 0″·65 (in adult female 0″·55), ear 0″·72, forearm

[1] In the *Stenodermata*, which are frugivorous or sanguinivorous in their habits, this character is not well developed, but the fundamental form of the teeth is the same as in other *Microchiroptera*.

[2] All species referred to in this paper, and of which descriptions may be found in my work on the Chiroptera, are simply named; other species since described have the place of publication of the original description indicated.

2″·5, third finger (metacarp. 1″·7, 1st ph. 1″·1, 2nd ph. 1″·65), fifth finger (metacarp. 1″·55, 1st ph. 0″·8, 2nd ph. 0″·8), tibia 0″·96, foot 0″·6.

Hab. Zanzibar.

Epomophorus labiatus, Temm.

The occurrence of well-preserved spirit specimens, in the collection received by me from Dr. Robb, enables me to define the species more correctly than I was able to do in 1878, when dried skins were alone available. While agreeing closely with *E. gambianus* in the total length of the head, the muzzle is shorter, and all other measurements, except those of the feet, are less. The fifth palate ridge also is not divided, being marked by a slight groove only. The following are the measurements of an adult female with well-worn teeth :—

Length: head and body 5″·0 inches, head 1″·95, eye from tip of nostril 0″·8, ear 0″·8, forearm 2″·85, thumb 1″·2, third finger 1″·95, (1st ph. 1″·3, 2nd ph. 2″·0) fifth finger (metacarp. 1″·9, 1st ph. 0″·9, 2nd ph. 0″·95), tibia 1″·15, foot 0″·75.

The fur extends much less densely upon the interfemoral membrane and legs than in *E. gambianus*; a very few hairs only appear upon the backs of the feet. In the female there are distinct, though rudimentary, shoulder-pouches. *Hab.* Abyssinia; Shoa; Malindi (Fischer and Peters).

Epomophorus comptus, Allen.

When describing this species the only specimen available was the skin of an adult female preserved in alcohol. Hence I was unable to add very many desirable particulars, especially those relating to secondary sexual characters and dentition. Fortunately this deficiency has been lately amply made good by a most excellent account of the characters furnished by an examination of four specimens preserved in alcohol, and a skin, by Dr. J. A. Smith, published in the 'Proc. Roy. Phys. Soc. Edinb.' 1880, pp. 362–69, the paper being accompanied by two woodcuts. The spirit specimens, consisting of two adult males and a female with a young male (which she was nursing when captured), I have since had an opportunity of examining in the British Museum (to the collection of which they have been presented by Dr. Smith), and I can endorse the very great accuracy of Dr. Smith's remarks.

The following measurements were made by me before seeing Dr. Smith's paper :—

—	Adult male	Adult male	Adult female	Adult female
Length of head	2·25	2·25	1·85	1·9
„ eye from tip of nostril . .	0·9	0·9	0·75	0·7
„ ear	0·9	0·9	0·9	0·9
„ forearm	3·7	3·7	3·3	3·4
„ thumb, metacarp.	0·5	0·6	0·4	0·45
„ „ phalanx (without claw) .	0·75	0·85	0·9	0·9
„ third finger, metacarp. . . .	2·55	2·7	2·3	2·35
„ „ 1st phalanx . .	1·65	1·7	1·6	1·55
„ „ 2nd phalanx . .	2·45	2·6	2·2	2·4
„ fifth finger, metacarp	2·45	2·6	2·2	2·3
„ „ 1st phalanx . .	1·3	1·25	1·15	1·2
„ „ 2nd phalanx . .	1·35	1·35	1·15	1·2
„ tibia	1·45	1·5	1·2	1·3
„ foot	0·95	0·9	0·75	0·8

In the fourth column I have arranged the measurements of the skin of the adult female specimen from which my original description was taken. The differences in the comparative measurements of the soft parts (notably of the ear and muzzle) between this and the female spirit specimen in the third column, are easily explained by the distortion always occurring even in the best preserved skins, and shows how very advisable it is never, if possible, to describe from skins. It may be noticed that the thumb and third finger of one of the male specimens is considerably shorter than those of the other, though the rest of the measurements agree remarkably closely.

In my description of this species I took care to remark that, *in the adult animal*, there were two upper incisors, for I had noticed how, in *E. franqueti*, the lateral upper incisors were liable to fall out (*vide* 'Catal. Chiropt.' p. 13), and these well-preserved specimens show that my suspicion that the dental formula did not really differ from that of the other species was quite correct. As Dr. Smith remarks, the immature male has four upper incisiors, quite similar to those in immature examples of *E. franqueti*, one of the males has lost both upper outer incisors, the other and the female has lost the left upper incisor only.

The presence of two upper incisors only, which was fixed upon as a distinguishing character by the author of the original description is, therefore, conclusively shown to be a delusive one. We have, however, in the form of the palate ridges, as previously noted by me (*op. cit.* p. 14, pl. II. fig. 5), a valuable specific character which can be relied upon, especially when taken into consideration with other characters. The figure of the palate ridges referred to above, taken from the single indifferently preserved female specimen, is sufficiently accurate, but, necessarily, not so good as the excellent woodcut of the same parts in an adult male individual, which illustrates Dr. Smith's paper. In this species, then, the third palate ridge (that between the second upper premolars) is undivided like the preceding ridge, while in *E. franqueti* (with which alone it may be confounded) the corresponding ridge is represented only by a prominent oval papilla at either side.

As in *E. franqueti*, the males of this species have large shoulder-pouches measuring nearly half an inch across in specimens in alcohol, probably much larger in living individuals. In these specimens a minute tail about one-tenth of an inch long is concealed among the hairs. I was unable to find any trace of one in the skin of the female specimen referred to, and there is certainly none in any specimen of *E. franqueti* I have yet examined. This part of the body being evidently in a vanishing condition, its suppression should not lead us, in the absence of other distinguishing characters, to found therefrom even a distinct race, much less a species.

Hab. West Africa (Lagos, Gaboon, Old Calabar, Ogoné).

Pteropus germaini.

Pteropus germaini, Dobson, 'P.Z.S.' 1878, p. 875.[1]

Ears shorter than the muzzle, concealed by the long fur of the head, triangular, obtusely pointed, thinly clothed throughout with soft hairs.

[1] Scarcely was my work on the Chiroptera out of the hands of the printer when I was enabled, through the kindness of M. Alphonse Milne-Edwards, to inspect some most interesting specimens of bats lately received by the Paris Museum, among which were the type of this species, and others to be referred to hereafter.

Fur long and woolly, like that of *Pt. aneiteanus*, on the back long like that of the head, directed backwards. Humerus and forearm rather thinly covered with straight fur like that of the back. The legs are clothed with long fur, which extends to the backs of the feet; the margin of the wing-membrane almost as far outwards as the extremity of the fifth finger is clothed with straight appressed hairs; the posterior margin of the narrow interfemoral membrane is quite concealed. Face in front of and immediately above the eyes light greyish-brown; head and the whole inferior surface of the body dark blackish-brown, interspersed with several shining greyish hairs, the shoulders and back darker, the rump and legs greyer; upper surface of the neck and shoulders pale yellow with reddish extremities.

Teeth like those of *Pt. medius*, the first upper premolar small, scarcely raised above the level of the gum, and occupying the centre of the small space between the canine and second premolar; last upper molar slightly larger than the first lower premolar, and about the size of the last lower molar.

Length (of a not quite adult female): head and body about 6″ inches; head 2″·3, ear 0″8, forearm 4″·7, thumb 2″·3, third finger (metacarp. 3″, 1st ph. 2″·5, 2nd ph. 3″·5), fifth finger (metacarp. 3″, 1st ph. 1″·5, 2nd ph. 1″·35), tibia 2″·2, foot 1″·7.

Hab. New Caledonia. Type in the collection of the Paris Museum.

This species resembles externally, to some extent, *Pt. aneiteanus*, but the very different form of the teeth at once distinguishes it. From *Pt. vetulus*, inhabiting the same islands, it is distinguished by the completely different colour of the fur, as well as by the absence of transverse basal ridges in the molars and premolars. Its food appears to consist, in part at least, of figs, as I found portions of these fruits in the mouth of the typical specimen.

Pteropus hypomelanus, Temm.

To the localities for this species add Cambodja.

Pteropus kerandrenii, Q. & G.

To the islands inhabited by this widely distributed species must be added New Caledonia, where are found two other species also, namely, *Pt. vetulus* and *Pt. germaini.*

Cynonycteris amplexicaudata, Geoff.

Add also Cambodja (M. Harmand, Paris Museum).

Cynonycteris collaris, Illiger.

Lord Lilford has brought from Cyprus, and presented to the collection of the British Museum, specimens of the large frugivorous bat of that island, which I find undoubtedly belongs to this species, hitherto known only from Equatorial and Southern Africa. I have already pointed out the close connection which exists between this species, *C. ægyptiaca*, and *C. amplexicaudata*, and this fact of specimens agreeing in all respects with South African examples occurring in Cyprus, where we should rather expect to find *C. ægyptiaca*, renders it extremely doubtful whether the characters used to separate the species are really of specific importance. More specimens are, however, required before this question can be finally settled.

Cynonycteris straminea, Geoff.

To synonyms of this species add *Pteropus palmarum*, Heuglin, 'Verh. Leop. Carol. Akad,' 1865, Heft 5, Nr. 3, 4.

Genus *Boneia*.[1]

Boneia, Jentink, Notes from the Leyden Museum, 1879, p. 117.

Characters generally those of *Cynonycteris*, but with two upper incisors only, separated from the canines and also in front; tail well developed.

Boneia bidens.

Boneia bidens, Jentink, *l.c.*

Ears longer than the muzzle, rounded at the tips; a prominent thickened lobule at the base of the outer margin of the ear-conch: nostrils deeply emarginate between, their inner margins projecting: eyes equally distant from the ears and from the extremity of the muzzle; upper and lower lips deeply grooved in front. Wings from the back near the spine, about one-sixth of an inch apart at their origin, and from the base of the toes between the first and second metatarsal bones; tail as long as the ear and very thick, projecting two-thirds its length beyond the interfemoral membrane. Face yellowish-brown; head and upper surface of neck and shoulders golden yellow; beneath dark brown throughout. Fur moderately long and dense, scarcely extending upon the membranes; the muzzle, ears, legs, and feet naked.

$$\text{Dentition :— inc. } \frac{1\text{–}1}{2\text{–}2}, \text{ c. } \frac{1\text{–}1}{1\text{–}1}, \text{ pm. } \frac{3\text{–}3}{3\text{–}3}, \text{ m. } \frac{2\text{–}2}{3\text{–}3}.$$

Cephalotes minor.

Cephalotes minor, Dobson, 'P.Z.S.' 1878, p. 875.

Resembles *C. peroni* closely in general structure, but less than half the size of adult specimens of that species; the feet are much smaller than in very young specimens of *C. peroni*, and the wing-membrane is attached to the outer toe, not to the space between the toes, as in that species; it also extends further outwards, terminating opposite the second joint of the next toe.

The teeth are also slightly different; the upper incisors are wider apart; the second upper premolar has not the prominent antero-internal basal cusp observed in *C. peroni*; and the first lower premolar scarcely rises above the gum.

Length: head and body 4″·5, tail 0″·6, head 1″·6, ear 0″·7, forearm 3″·2, first finger 1″·3, third finger (metacarp. 2″·0, 1st ph. 1″·5, 2nd ph. 1″·9), fifth finger (metacarp. 2″·0, 1st ph. 1″·1, 2nd ph. 1″·1), tibia 1″·1, calcaneum 0″·25, foot 0″·8.

Hab. Amberbaki, New Guinea.

Type in the collection of the Paris Museum.

[1] This appears to be the proper position of the genus, of which I have not yet had an opportunity of seeing the type of the species on which it is founded.

SUBORDER II.—MICROCHIROPTERA.

Family RHINOLOPHIDÆ.

Rhinolophus luctus, Temm.

Hab. Mount Willis, Java, 2500 feet (Baron v. Hügel). This new locality for *R. luctus* also indicates, as I have previously remarked, that this species appears to be restricted to the highlands of the countries which it inhabits.

Rhinolophus acuminatus, Ptrs.

To the localities of this species add Laos, Siam, (M. Harmand, Paris Museum).

Rhinolophus affinis, Horsfield.

Add also Cochin China (M. Harmand, Paris Museum).

Rhinolophus minor, Horsfield.

Dr. W. Peters remarks [1] that I have unaccountably confounded *Rh. cornutus*, Temm. with this species, which, he states, is to be distinguished from it, as Horsfield's figure shows, by the superior margin of the central connecting process behind the sella being obtusely rounded off, as in *Rh. affinis*, and not sharply pointed.

The following notes will, I think, sufficiently explain why I still regard *Rh. cornutus*, Temm. a synonym of *Rh. minor.*

1. With respect to Horsfield's figures they are not only badly executed, but were taken, as the types show, from very badly preserved specimens, and therefore cannot be depended upon as correct.

2. The type of *Rh. minor* (lately in the collection of the India Museum, and now transferred to the British Museum) agrees so closely with Horsfield's description that there can be no doubt of its being *really* the type of the species. In it the part of the noseleaf referred to above is very different in shape from the corresponding part in *Rh. affinis* (to which Dr. Peters likens it), it is triangular and pointed, very like that of *Rh. landeri* (see 'Catal. Chiropt. Br. Mus.' pl. vii. fig. 9), and quite similar to that of two specimens from Japan, lately added to the collection of the British Museum, which I have no hesitation in recognising as examples of *Rh. cornutus*, Temm. But in other specimens of *Rh. minor*, especially in those of smaller size, I have observed that the superior margin of the posterior connecting process is even more acute, in some exceedingly so, constituting the variety *Rh. pusillus*, Peters, (not Temminck); in others, still smaller, the terminal portion of the posterior lancet-shaped nose-leaf is broad, with straight sides, forming almost an equilateral triangle, very different from the corresponding narrow terminal process in other individuals, constituting another variety, which, until lately, I considered a distinct species and named *Rh. garoensis.* As a further indication of how liable this species is to vary, as I have previously remarked, the position and size of the second lower premolar is very uncertain, being found in some small individuals of moderate size and standing in the tooth-row, in larger specimens minute and quite external, and *vice versâ.*

[1] *M. B. Akad. Berl.* 1880, p. 24.

In the following table the measurements of eight specimens are given, the localities of each, the position of the second lower premolar, the place of attachment of the wing membrane to the posterior extremities, and the nominal specific title of each being indicated beneath:—

	1	2	3	4	5	6	7	8
	♀	♀	♀	♀	♀	♀	♂	♂
Length, head and body . . .	...	1·75	1·65	1·5	1·5	1·65	1·75	1·55
„ tail	0·75	0·9	0·65	0·7	0·75	0·85	0·75	0·7
„ head	...	0·7	0·65	0·6	0·65	0·7	0·7	0·65
„ ear	0·52	0·7	0·65	0·5	0·55	0·6	0·63	0·55
„ forearm	1·45	1·6	1·4	1·3	1·45	1·5	1·55	1·4
„ third finger, metacarp. .	1·0	1·15	0·95	1·0	1·05	1·1	1·1	1·05
„ „ 1st phalanx .	0·4	0·5	0·4	0·4	0·43	0·45	0·45	0·43
„ „ 2nd „ .	0·6	0·7	0·55	0·55	0·6	0·7	0·7	0·6
„ fifth finger, metacarp. .	1·05	1·2	1·0	1·0	1·0	1·15	1·15	1·05
„ „ 1st phalanx .	0·35	0·4	0·35	0·34	0·35	0·4	0·38	0·35
„ „ 2nd „ .	0·4	0·5	0·4	0·4	0·4	0·5	0·45	0·4
„ tibia	0·6	0·65	0·5	0·6	0·5	0·6	0·6	0 6
„ foot	0·25	0·3	0·25	0·25	0·28	0·26	0·26	0·25

In 1, 2, 3, and 4, the second lower premolar stands in the tooth-row, and is distinctly visible without the aid of a lens, in 5 it is half external, in 6 and 7 it is three-fourths external, in 8 it is quite external to the tooth-row, scarcely visible without the aid of a lens and the first and third premolars are closely approximated. But neither the form of the noseleaf nor the size of the individual corresponds to these differences; in 2 and 4, the largest and smallest respectively, this premolar stands in the tooth-row and can be easily seen with the naked eye; in 1, 2, and 5 the noseleaf corresponds exactly in form, in 4 and 8 the posterior connecting part of the sella develops a long, very acutely pointed, process, while in 6 and 7 the form of the same part is intermediate. Again in 1, 2, and 8 the wing-membrane is attached to the tibia immediately above the ankles, while in 3, 4, 5, 6, and 7 it extends to the ankles or even to the tarsus; 1 is the type of *Rh. minor*; 2 (from Japan) undoubtedly represents *Rh. cornutus*, Temminck; 4 *Rh. garoensis*, Dobson, while 3, 5, 6, 7, and 8 should, according to Dr. Peters, be referred to *Rh. pusillus*, Temminck.

The specimens from Japan differ from the type of *Rh. minor* only in being larger throughout; but, as I have shown in the table above (in columns 6 and 7), in this respect intermediate forms (from Tsagine, Upper Burma, collected by Dr. Anderson) are found, while the shape of the nose-leaf, and the development and position of the second lower premolar, are again intermediate between these forms and that of which the measurements are given in column 8, and which would be regarded as a typical *Rh. pusillus*.

For these reasons I have considered all these forms as but different phases of the same species; for, although individuals like those of which the measurements are given in columns 2 and 8, appear to differ so widely in size, in the development and position of the second lower premolar, and in the form of the posterior connecting process of the nose-leaf, yet such perfectly intermediate examples are found that it becomes impossible to say under which title the latter should be classed.

Rhinolophus euryale, Blasius.

The Alps and the Pyrenees have been hitherto considered the northern limit of the distribution of this species in Europe, but lately M. Lataste has discovered it at Saint Paterne, a place north of the Loire.[1] Dr. E. L. Trouessart remarks [2] that as M. Lataste had previously obtained specimens of the same species at Vernet-les-Bains (Pyrénées Orientales) it may be fairly supposed that it is distributed in greater or less abundance throughout N.W. and S.W. France.

Rhinolophus hipposideros, Bechst.

The types of *Rh. pusillus*, Temm., in the collection of the Leyden Museum, are, as I have previously remarked, undoubtedly specimens of *Rh. hipposideros*, and I have, therefore, considered Temminck's species identical with that previously described, especially as his description quite agrees with the characters afforded by the types. Prof. Peters, however, considers [3] that I should not have been led to believe that the *so-called* types are *really* the types, and suggests that an interchange of labels may have taken place, remarking that I should have attended more closely to the figure of *Rh. pusillus* which accompanies Temminck's description. To this my reply must be much the same as in the case of *Rh. minor* et *cornutus* (vide supra) namely, (1) that Temminck's figures cannot be depended upon; (2) that even if *Rh. pusillus*, Temminck, be as defined by Dr. Peters, I can only (for the reasons stated above under *Rh. minor*) consider it a variety of *Rh. minor*; and (3) that in taking the types as a guide I acted only as Dr. Peters did years ago, in the case of Spix's Brazilian types, and for which he deserves the thanks of every naturalist.

To the synonymy of this species, as given by me, should be added *Vespertilio minutus*, Montagu, 'Trans. Linn. Soc.' 1808, p. 163.

Rhinolophus ferrum-equinum, Schreb.

All the known Ethiopian species of the genus are more or less related to this species, agreeing with it in the low antitragus which is separated from the rest of the outer margin of the ear-conch by a shallow obtuse-angled notch, also in the general form of the nose-leaf, in the very small size of the second lower premolar (which is quite external to the tooth-row, the first and third premolar being closely approximated), and more or less in the closeness of the second upper premolar to the canine. It is worthy of notice that no species having all these characters in common has as yet been found beyond the limits of the Ethiopian and Palæarctic regions.[4] Of these allied Ethiopian forms I have recognised four as species, namely—*Rh. landeri*, *clivosus*, *capensis*, and *æthiops*, but between these and *Rh. ferrum-equinum* come several more or less intermediate forms presenting slight differences either in the nose-leaf, in the position and size of the first upper premolar, in measurements, or in the colour of the fur, which I have included in the synonymy of *Rh. ferrum-equinum* and *Rh.*

[1] I have to thank M. Lataste for sending me specimens of this species (and of others to be referred to farther on), of which he obtained 200 individuals at the above-named place.

[2] *Le Naturaliste*, No. 16, 1879, p. 125.

[3] *M. B. Akad. Berl.* 1880, p. 23.

[4] *Rh. ferrum-equinum* has been found in the Himalayas, but they are on the boundary of the Palæarctic Region.

capensis, leaving it to subsequent observers, when more material is available in our Museums, to say how far some of them may be regarded as representing permanent varieties. Of these some were not included in my work, either owing to accident, or because I had not been able to obtain in time before publication an examination of the types or copies of the papers in which they were described. These I now proceed to notice.

Rhinolophus macrocephalus.

Rhinolophus macrocephalus, Heuglin, 'Reise in Nordost-Afrika,' ii. p. 22 (1877).

It appears quite evident that this is only another name for *Rh. fumigatus*, Rüpp. which I have regarded as a small form of *Rh. ferrum-equinum* with dark-coloured fur.

Rhinolophus lobatus.

Rhinolophus lobatus, Peters, 'Reise nach Mossambique,' Säugeth, p. 41, pl. 9, 13, figs. 16, 17 (1852).

To this form I accidentally omitted all reference (in the 'Catal. Chiropt. Br. Mus.') although I had examined the type in the collection of the Berlin Museum, and find the following record in my note-book.

Nose-leaf like that of *Rh. affinis*, the summit of the posterior connecting process of the sella more convex and covered with a very few hairs: the posterior lancet-shaped leaf longer; ears and teeth as in *Rh. ferrum-equinum*; wings from the ankles, interfemoral membrane slightly triangular behind; extreme tip of the tail alone projecting; fur, dark slate-blue (in alcohol). Length (of an adult female): head and body 1″·9 inches, tail 1″·0, ear 0″·7, forearm 1″·7, thumb 0″·25, third finger 2″·6, fifth finger 2″·2, tibia 0″·7, foot 0″·3, nose-leaf 0″·5 × 0″·32.

Hab. Mozambique, Galitja.

Rhinolophus æthiops, Ptrs.

I have received two specimens of this species from Dr. Robb, Zanzibar, which differ in no important respect from other specimens hitherto known only from the West Coast of Africa.

Rhinolophus hildebrandtii.

Rhinolophus hildebrandtii, Peters, 'M.B. Akad. Berl.' 1878, p. 195, pl. 1, fig. 1, 1 a.

In general form very like *Rh. æthiops* but somewhat larger, the shape of the ears and of the nose-leaf almost identical with those of that species, but the central erect process of the sella is much broader and higher, and more rounded off above, and the posterior lancet-shaped part of the leaf is rather thickly clothed with hair. Wings from the ankles; the last and half the ante-penultimate caudal vertebræ projecting abruptly, margined by a narrow piece of membrane on either side. The following are measurements of an adult specimen (a skin preserved in alcohol), and of an adult specimen of *Rh. æthiops* from Zanzibar.

		in.	in.
Length:	head and body		2·5
,,	tail	1·5	1·3
,,	ear	1·15	0·95
,,	fore-arm	2·4	2·25
	thumb	0·3	0·3

		in.	in.
Length : third finger, metacarp.		1·6	1·45
„ „	1st phalanx	0·8	0·7
„ „	2nd „	1·4	1·25
„ fifth finger,	metacarp.	1·75	1·65
„ „	1st phalanx	0·55	0·5
„ „	2nd „	0·7	0·6
„ tibia		1·0	0·95
„ calcaneum		0·6	0·55
„ foot		0·55	0·5

Hab. Ndi, Taita, East Africa.

An examination of a specimen of this species (named by the describer) in the collection of the British Museum enables me to make the above notes. A careful comparison of that specimen with specimens of *Rh. æthiops* from Zanzibar, while showing the differences I have indicated, at the same time shows also their close connection in all other respects ; and I can scarcely regard *Rh. hildebrandtii* as more than a hill form of *Rh. æthiops*, standing in much the same relation to that species as *Vesperugo lasiopterus* to *V. noctula*, though differing much less in size than the latter variety.

Triænops persicus.

Triænops persicus, var. *afer*, Dobson, 'P.Z.S.' 1879, p. 717.

An examination of two well-preserved spirit specimens of this species in Dr. Robb's collection from Zanzibar, and of others sent to the British Museum from Ushambola, enabled me to affirm the identity of the Persian and African forms in the paper referred to above where I have compared their measurements, &c.

Hab. Persia (Shiraz) ; East Africa (Mombasa, Ushambola, Zanzibar).

Phyllorhina tridens, Geoff.

This species, as well as the preceding, extends into both Asia and Africa. Specimens in the collection lately reeeived by the British Museum from the India Museum are labelled 'El Leil, Mesopotamia,' and 'Bushire, Persia.' The basioccipital bone between the anditory bullæ is, in this species, proportionally much narrower than in other species of *Phyllorhina*, and approaches that of *Rhinolophus* in this respect.

Phyllorhina tricuspidata, Temm.

To list of localities of this species add New Guinea (M. Raffray, Paris Museum).

Phyllorhina commersonii, Geoff.

Add Malindi, East Africa (Fischer and Peters).

Phyllorhina armigera, Hodgson.

Add Cochin China (M. Harmand, Paris Museum).

Phyllorhina diadema, Geoff.

Add also Cochin China (M. Harmand) ; Sanghir Island (M. Laglaize). The specimens from the latter locality differ from all others hitherto examined by me in the great development of the central projecting ridge of

the sella, which, in one instance, projects almost as far forwards as the corresponding part of the nose-leaf in *Ph. cyclops*; the blunt projection in the centre of the upper margin of the transverse terminal part of the leaf is also much more defined than in other specimens of this species, and in one from Sanghir Island corresponds to a large cell behind.

Phyllorhina larvata, Horsfield.

To list of localities add Cochin China (M. Harmand, Paris Museum).

Phyllorhina bicolor, Temm.

Add also Cochin China (M. Pierre, Paris Museum).

Cœlops frithii, Blyth.

To my description of this most remarkable species the following may be added:—

The calcaneum is weak, but distinct, nearly one-fifth of an inch in length, and projects at its extremity slightly beyond the interfemoral membrane; there is no trace of a tail externally; the wing-membrane extends to the proximal extremity of the metatarsus; the female has pubic teat-like appendages, as in the other species of *Rhinolophidæ*; the terminal phalanx of the fourth finger ends in a large T-shaped process. The measurements agree closely with those of the specimen in the Leyden Museum from which my description ('Catal. Chiropt. Br. Mus.' p. 153) was taken.

To the localities of this species add Laos (in the roof of the Great Pagoda at Lakhon, collected by M. Harmand) and Bantam, Java. In the Laos specimens the fur is very dark brown above, (appearing black in alcohol), beneath paler, the terminal third of the hairs ashy; ears light brown; membranes very dark brown or black.

Family NYCTERIDÆ.

To the regional distribution of this family add the Australian region (Austro-Malayan and Australian sub-regions).

Megaderma spasma, L.

To localities add Laos and Macassar.

Megaderma gigas.

Megaderma gigas, Dobson, 'P.Z.S.' 1880, Pt. iii. p. 461, pl. xlvi.

Although many times larger, yet in general external structure this species agrees very closely with *M. spasma*, the relative proportions of parts, however, being somewhat different. Thus the posterior lobe of the tragus, though similarly shaped, is proportionately shorter, while the anterior lobe is much broader at the base, more convex forwards, and obtuse at the tip; the nose-leaf also, though almost identical in shape, is not much larger than that of that species.

While in *M. spasma* the extremity of the second finger does not extend as far as the middle of the first phalanx of the third finger, in this species, as in *M. frons*, it extends beyond it.

Tail rudimentary, two short vertebræ only project beyond the extre-

mities of the ischiatic bones, and are quite concealed between the two layers of integument, divided from the dorsal and ventral surfaces of the body, forming the base of the large interfemoral membrane.

The single specimen, an adult male, is very peculiarly coloured, somewhat like the specimen of *M. lyra*, in the writer's collection previously described.[1] As in it, the general colour of the fur, ears, nose-leaf, and membranes is white, the base of the fur, upon the upper surface only, being pale slate-blue, the colour so characteristic of the genus; unlike the other known species, the extremity of the carpus, the thumb, and the membrane between the thumb and the second finger are clothed with short hairs, in the type specimen of a white colour.

The teeth scarcely differ in general form from those of *M. spasma*, but, as in the Ethiopian species of this genus, there is no minute upper premolar, and the dental formula therefore agrees with that of *M. frons*.

The rudimentary premaxillæ resemble more closely those of the *Rhinolophidæ* than those of any other species of *Megaderma*. As in that family, they project considerably beyond the line of the canines, from which they are also separated by a diastema on either side, and two small depressions in the gum may be seen, which appear to be the empty sockets of a pair of rudimentary teeth, occupying precisely the same relative position as in the species of *Rhinolophidæ*, an additional indication of the close affinity of the *Nycteridæ* to that family.

In the skull, as I have generally observed in the larger species of each genus, the sagittal crest is well developed, and the pair of ridges into which it divides in front are so strongly marked as to cause the frontal bones between them to appear considerably hollowed. These ridges terminate on each side in a blunt but well-marked post-orbital process, which, however, as in *M. spasma*, is not perforated by a foramen. In this respect, therefore, the skull agrees with that of *M. spasma*, which inhabits part of the same zoological region, though apparently agreeing more closely with *M. frons* and *M. cor.* in the flattened and expanded frontals, and in the absence of a minute upper premolar:—

Length (of an adult male): head and body (inches) 5″·3, head 1″·9, nose-leaf 0″·6, ear 2″·2, tragus (anterior lobe 0″·45, posterior lobe 1″·0), forearm 4″·2, thumb 0″·8, second finger (metacarpal 3″·3, phalanx 0″·6), third finger (metacarp. 2″·7, 1st ph. 1″·85, 2nd ph. 3″·6), fourth finger (metacarp. 3″·1, 1st ph. 1″·0, 2nd ph. 1″·5), fifth finger (metacarp. 3″·3, 1st ph. 1″·25, 2nd ph. 1″·1), tibia 1″·7, calcaneum 1″·1, foot 1″·1.

Hab. Mount Margaret, Wilson's River, Central Queensland, Australia (captured by Mr. Wilson).

The single specimen from which the above description was taken, was sent by Dr. Schuette to the Göttingen Museum, accompanied by a note from Mr. Krefft on the colour of the fur and membranes in the recently killed animal. He describes the fur on the upper surface as leaden or slate-coloured, with greyish extremities, beneath white; the ears, nose-leaf, and membranes flesh-coloured, with the exception of the band of integument uniting the ears in front, which is deep blood-red.

This species, in comparison with the four other known species of the genus, is really gigantic in size, exceeding the largest, namely, *M. lyra*, as much as the Noctule (*Vesperugo noctula*) exceeds the Pipistrelle (*V. pipistrellus*). If its habits be similar to those of *M. lyra* (see my Monograph

[1] *Catal. Chiropt. Brit. Mus.* p. 157.

of the Asiatic Chiroptera, p. 77, 1876), it must be a very tiger among bats, able, from its superior size, great development of the volar membranes, and powerful canine teeth, to prey not only upon every known species of *Microchiroptera* inhabiting the Australian region, but also, probably, upon every other species of the whole sub-order, for one species only—*Phyllorhina commersonii.* Geoff. (=*Rh. gigas.* Wgnr)—exceeds it in the length of the forearm, yet in that species the forearm is disproportionately long, and in general measurements *Megaderma gigas* has greatly the superiority —it is therefore also the largest known species of *Microchiroptera.*

The position of this species in the genus appears to be between *M. spasma* and *M. cor.*, but more closely related to the latter, with which it agrees in the presence of post-orbital processes (though comparatively very short), and in the absence of the minute first upper premolar.

To the great liberality of Prof. Ehlers, of the Göttingen Museum, I owe the opportunity which has been afforded me of examining and describing the type of this most interesting species.

Megaderma cor. Ptrs.

Hab. Abyssinia; Malindi; Mombasa.

Megaderma frons, Geoff.

To the localities of this species add Kau, River Osi, East Africa (Fischer and Peters). Heuglin (*op. cit.*) notices this species from the Upper Nile, south of the fifteenth parallel of latitude, and remarks that it occurs along the banks of streams, and in thick jungle in the tops of trees; that it sees well by day, and occasionally flies about in full sunshine. This agrees sufficiently closely with Capt. Speke's account of the same species quoted by me in 'Catal. Chiropt. Brit. Mus.' p. 160.

Nycteris hispida, Schreb.

To the localities of this species add Kitui, Pokomo-land (Fischer and Peters).

Nycteris grandis, Ptrs.

The occurrence of two perfectly adult specimens of this species in Dr. Robb's Zanzibar Collection, not only adds a new locality, but their size shows that the type in the Leyden Museum, and the larger specimen in the British Museum, are but immature individuals. The following are the measurements of an adult male:—

Length: head and body, 3″ inches, tail 3″, head 1″·15, ear 1″·35, tragus 0″·3 × 0″·1, forearm 2″·5, thumb 0″·65, third finger (metacarp. 1″·8, 1st ph. 1″·2, 2nd ph. 1″·5), fifth finger (metacarp. 2″·2, 1st ph. 0″·7, 2nd ph. 0″·65), tibia 1″·2, calcaneum 1″·0, foot 0″·55.

The second lower premolar in these specimens is much smaller proportionately, evidently owing to the growth of the adjoining teeth, and is crushed in between the first premolar and first molar.

Nycteris æthiopica, Dobson.

The tragus is incorrectly given ('Catal. Chiropt. B. M.,' p. 165) as narrower than that of *N. javanica.* It is really broader and altogether larger, as the well-preserved specimens in Dr. Robb's collection show, the mistake in my original description having arisen from the contracted con-

dition of the tragus in the dried skins then only known. The following are the measurements of one of these specimens: Length: head and body 2″·35, tail 2″·25, head 0″·9, ear 1″·15, tragus 0″·3 × 0″·15, forearm 1″·95, thumb 0″·55, third finger (metacarpal 1″·4, 1st ph. 1″·0, 2nd ph. 1″·2), fifth finger (metacarp. 1″·65, 1st ph. 0″·55, 2nd ph. 0″·55), tibia 0″·95, calcaneum 0″·7, foot 0″·45.

Nycteris thebaica, Geoff.

N. angolensis, Ptrs., has been lately reported by its describer from Ndi, Taita, north of Zanzibar, on the opposite side of the African continent from Angola. Thus it occurs in a country very close to Zanzibar, whence comes *N. fuliginosa*, Ptrs., originally described from Mozambique. In Western Africa *N. damarensis*, Ptrs., from Damara-land, appears as an intermediate form between *N. angolensis* from the north and *N. capensis* from the south. The geographical chain is thus completed. It is difficult to imagine such allied forms meeting and not interbreeding freely. I have already remarked that I do not think the size or position of the second lower premolar (which is more or less rudimentary in all the known Ethiopian species of the genus) of sufficient importance to found a species upon. I have pointed out its variability in *N. grandis*, and I believe that the different sizes and positions of this tooth as exhibited in the following table are but other examples of its variability in a single species, namely—in *N. thebaica*:

a. Second lower premolar quite internal to the tooth-row.
- *a′*. Second lower premolar minute . . . . . 1. *N. thebaica.* Egypt; Abyssinia.
- *b′*. Second lower premolar larger . . . . . 2. *N. angolensis.* Angolo; Pokomo-land.

b. Second lower premolar half internal to the tooth-row.
- *c′*. Second lower premolar larger . . . . . 3. *N. damarensis.* Damara-land.

c. Second lower premolar in the tooth-row.
- *d′*. Second lower premolar minute . . . . . 4. *N. capensis.* Zambesi; Natal.
- *e′*. Second lower premolar larger . . . . . 5. *N. fuliginosa.* Zanzibar; Mozambique.

Family VESPERTILIONIDÆ.

Plecotus auritus, L.

Sir Joseph Fayrer has lately sent me specimens of this bat from Sutherlandshire; it therefore extends from the extreme south almost to the extreme north of Great Britain, though probably not found in the Shetlands, for Mr. Ernest Brown, now (August) visiting these islands, has at my request particularly inquired into the presence of bats there, and writes to me that he has never seen one since his arrival, and that the inhabitants assure him that such animals are quite unknown there.

This widely distributed species has also lately been recorded by Dr. Peters from Nikko, Japan, so that it extends from the extreme west to the extreme east of the Palæarctic Region.

Plecotus ustus, Heuglin, is re-described in the 'Reise in Nordost-Afrika,' p. 30 (1877), but whether that (?) species really belongs to the genus *Plecotus* or not I am quite unable to judge from the description, which omits all reference to the dental characters.

Vesperugo velatus, Is. Geoff.

Add Bolivia to the localities of this species.

Vesperugo serotinus, Schreb.

Considering the great variability of specimens of this species, which are occasionally found to vary more even in the same region than specimens collected in very distinct zoological regions many thousands of miles apart (for instance, specimens of the Serotine from Central America have been found by me to present not the very least difference when compared with European examples), I am led to believe that the specimens from Yunan described by me under the name of *V. andersoni* ('Proc. As. Soc. Beng.' 1871, p. 211) represent but a variety or perhaps local race only of this species.

To the synomymy also add *Vespertilio incisivus, serotinus et palustris*, Crespon, 'Faune méridionale,' p. 11 (1844), (*vide* Trouessart, 'Bull. Soc. des Sci. Nat.' Nimes, févr. 1879, p. 35); and for the variety, *V. fuscus*, add the locality Folsom, El Dorado, California.

Vesperugo borealis, Nills.

Vesperugo borealis, Dobson, 'Scientific Results of the Second Yarkand Mission,' —Mammalia, p. 12 (1879).

To the description of this species (as given by me in the 'Catal. Chiropt. Br. Mus.') may be added that a fringe of fine straight hairs extends round the upper lip in front beneath the nostrils. This character affords, in the case of badly preserved skins of immature specimens, an easy method of distinguishing *V. borealis* from *V. discolor*, in which this fringe is quite absent.

Vesperugo maurus, Blas.

In a paper, of which I have only recently been made aware by Dr. Forsyth Major,[1] the identity of *Vespertilio savii*, Bonap. *Vespertilio bonapartii*, Savi, and *Vesperugo maurus*, Blas. has been demonstrated to the satisfaction of the author and of others, but as the types of the first two named species are not forthcoming, and as the descriptions are incorrect or insufficient, I retain Blasius' name.

In the collection of the Göttingen Museum, I have lately found a specimen perfectly indistinguishable from this species, which was carefully labelled as having been sent from Popayan, in New Granada, in 1844, by Degenhardt. The presence of a single specimen is, of course, not sufficient ground to extend the distribution of this species to the Neotropical Region, the Chiroptera of which (with one exception only—*Vesperugo serotinus*, as I have shown[2]) are quite distinct from those of any of the zoological regions of the Eastern Hemisphere. There are, however, in the same collection, several other specimens of species, evidently Neotropical, which are labelled 'Popayan' (to be referred to hereafter), and with which this specimen agrees precisely in the state of preservation. It is also noteworthy that *V. maurus* has been found in Europe at very high elevations only, along the Alps, and in this respect the South American habitat given

[1] In *Atti della Soc. Tosc. di Sci. Nat.* iii. fasc. i. Pisa, 1877.
[2] *Catal. Chiropt. Br. Mus.* p. 193.

agrees very well, for Popayan is situated on an elevated plain in the Andes, 6000 feet high.

If, then, specimens of this species have really come from such very distinct and distant zoological regions, and exhibit so few differences, it becomes evident that we must consider the Oriental representatives of this species described under the names *Vesperugo mordax*, Ptrs., *V. pulveratus*, Ptrs., and *V. austenianus*, Dobson, as a distinct species, which, although agreeing remarkably in general structure and even in the colour of the fur with *V. maurus*, differs in its conspicuously greater size (forearm 1″·6) in the very shallow emargination in the upper half of the outer margin of the ear-conch, in the considerably less degree in which the extremity of the tail projects from the interfemoral membrane, and in the much greater development of the first upper premolar, which, although the second premolar is also close to the canine, may be seen without difficulty from without.

In an interesting paper,[1] Sgnr. E. Regalia has noted the variations presented by about thirty individuals of this species collected in Northern Italy. His observations may with much advantage be attended to by those who are inclined to found species on slight differences in structure and colour. Among many other important differences noted by this observer the variability in the general measurements, and in the size and presence or absence of the first upper premolar may be especially referred to here. In his table of measurements the length of the forearm (of which I had given the average measurement as 1·35 inches) is shown to vary from about 1·28 to 1·45 inches. Also both first upper premolars were found in ten individuals; in three the first premolar was present on the right side only; while in one this tooth was absent on both sides.

Vesperugo brunneus.

Vesperugo (Vesperus) brunneus, O. Thomas, 'Ann. Mag. Nat. Hist.' Aug. 1880, p. 165.

Muzzle broad and flat above, the grandular prominences well-developed, increasing its width. Ears slightly shorter than the head, with broadly rounded-off tips, outer margin of the conch faintly convex, angularly emarginate opposite the base of the tragus, the terminal lobe elongated; tragus reaching its greatest width above the middle of the inner margin, obliquely truncated above, inner margin straight, outer margin almost parallel to it, with a small triangular basal lobule.

Wings from the base of the toes; post-calcaneal lobe well-developed; tail wholly contained within the interfemoral membrane.

Fur, above and beneath, dark-brown.

Outer upper incisors minute, barely one-third the height of the large unicuspidate inner incisors; no minute first premolar. Lower incisors at right angles to the direction of the jaws.

Length (of an adult female): head and body 1″·8 inches, tail 1″·35, head 0″·6, ear 0″·55, tragus 0″·2, forearm 1″·33, third finger 2″·27, fifth finger 1″·6, tibia 0″·5, foot 0″·35.

Hab. Old Calabar. Type in the collection of the British Museum. Distinguished from *V. capensis* by its unicuspidate upper incisors; from *V. maurus*, not only by the absence of the minute upper premolar, but also by the tail being wholly included within the interfemoral membrane.

[1] Alcune variazione e particolarita osservage nel *Vesperugo Savii* Bonap. nota di E. Regalia. R. Instituto Lombardo, 25 Apr. 1878.

Vesperugo noctula, Schreb.

To the localities of this species add Hekodate, Yesso, Japan (Hilgendorf and Peters).

Vesperugo vagans.

Vesperugo vagans, Dobson, 'Ann. Mag. Nat. Hist.' Aug. 1879, p. 135.

Ears short, triangular, like those of *V. pipistrellus*; the tragus reaches its greatest width in the upper third, inner margin slightly concave above, outer margin straight in lower two-thirds, with a small rounded lobule at the base not succeeded by an emargination, upper margin broadly rounded off, in general outline, on the whole, like that of *V. maurus.*

Post-calcaneal lobule well developed; the rudimentary last caudal vertebra alone projecting. Fur above, dark reddish-brown; beneath similar, but paler at the extremities. The membranes are nearly naked.

Upper incisors like those of *V. temminckii*; the inner incisor on each side moderately long and unicuspidate, the outer very short and conical, scarcely exceeding the cingulum of the inner incisor in vertical extent, but nearly equal to that tooth in cross-section at the base; lower incisors nearly at right angles to the direction of the jaws, trifid and crowded; first upper premolar extremely small, with difficulty seen even with the aid of a lens, in the inner angle between the closely approximated canine and second premolar.

Length (of the type, an adult female): head and body 2″·0, tail 1″·8, head 0″.65, ear 0″·5, tragus 0″·2, forearm 1″·55, thumb 0″·3, third finger (metacarp. 1″·45, 1st ph. 0″·6, 2nd ph. 0″·75); fifth finger (metacarp. 1″·13, 1st ph. 0″·35, 2nd ph. 0″·35), tibia 0″·6, foot 0″·38.

Type in the collection of the British Museum. *Hab.* uncertain, from some part of the North American continent or from the West Indies. Mr. Matthew Jones sent the specimen to the British Museum in the same bottle with some fishes and other specimens collected at Bermuda, but he informed me (during my visit to him at Halifax, N.S.) that he could not say where the bat in question was obtained.

During my visit to Bermuda, I went over Mr. Bartram's collection, and found only specimens of *Atalapha cinerea* and of *Vesperugo noctivagans*, which he assured me were the only species of bat ever obtained in the island.

Vesperugo abramus, Temm.

Vespertilio akokomuli, Temminck (Monogr. 'Mammal.' ii. p. 223, pl. 57, figs. 8, 9), was accidentally omitted in the list of synonyms of this species ('Catal. Chiropt. B.M.' p. 226), although given as such in my 'Notes on Dr. Severtzoff's Mammals of Turkestan' ('Ann. Mag. Nat. Hist.' 1876, p. 130). Dr. Jentink has called attention to this omission in 'Notes from the Leyden Museum,' ii. pp. 37–40 (1879).

Signor E. Regalia has published some interesting notes[1] on this species, recorded from Italy by Dr. Forsyth Major, in which he discusses the relative values of the characters used to distinguish it from *V. pipistrellus.*

Dr. E. L. Trouessart has lately[2] recorded the capture, by M. Lataste, of a specimen of this species at Cadillac, Gironde, hitherto unknown west

[1] *Estratto dal processo verbale della Societa di Sci. Nat. res. in Pisa*, 1880.

[2] *Le Naturaliste*, 1879, p. 125.

of the Rhine, and Mr. Oldfield Thomas has pointed out to me a specimen in the British Museum, lately received from the Aru Islands.

Vesperugo kuhlii, Natt.

Pipistrellus lepidus, Blyth ('Journ. Asiat. Soc. Beng.' xiv. p. 340), and, probably, *Scotophilus rusticus*, Tomes ('P.Z.S.' 1861, p. 35), should be added to the list of synomyms. According to the description of *S. rusticus*, it must come very close to this species, with which it agrees in dentition, in the white margin to the wings behind, in size, &c., but this question cannot be definitely settled without an inspection of the type, which both Dr. Peters and the writer have in vain endeavoured to obtain from Mr. R. F. Tomes.

To the localities of this species add also Cadillac, Gironde (Lataste and Trouessart).

Vesperugo temminckii, Czetzsch.

Vesperugo senaarensis et hypoleucus Fitzing and Heugl. ('Sitzungb. Akad. Wein.' 1866) are again referred to by Heuglin (*op. cit.* p. 32); they appear to be identical with this species.

Vesperugo georgianus, F. Cuv.

Dr. Jentink having examined the types of *Vespertilio erythrodactylus*, Temminck (which escaped my notice on both occasions of visiting the Leyden Museum), has determined their identity with specimens of this species.

Vesperugo nanus, Ptrs.

To localities add Kitui, Ukamba, and Ndi, Taita, East Africa (Hildebrandt and Peters).

Vesperugo noctivagans, Leconte.

Of this species, which has probably the highest northern range among the bats of North America (see 'Catal. Chiropt. B. M.' p. 239) I observed specimens, easily distinguished by the peculiar colour of the fur, in Mr. J. T. Bartram's collection, during my late visit to the island of Bermuda. It has previously been recorded from Bermuda by Mr. J. Matthew Jones.[1]

Vesperugo doriæ, Ptrs.

In my description of this species ('Catal. Chiropt. B. M.' p. 240) at end of line 22 from top of page the word 'inner' has been accidentally substituted for 'outer.'

Scotophilus borbonicus, Geoff.

To the synonyms of this species add *Nycticejus flavigaster et murinoflavus*, Heuglin ('Verh. L. Carol. Akad.' 1861, pp. 14, 15, and 'Reise in Nordost-Afrika,' 1877, pp. 32, 33), and to localities Sierra Leone and Cape Coast Castle.

Atalapha cinerea, P. de B.

Specimens of this easily distinguished species were also found by me in Mr. Bartram's collection at Bermuda, thus confirming Mr. J. Matthew

[1] *Guide to Bermuda*, p. 122.

Jones's record (*l.c.*). Examples from Buenos Ayres have lately been added to the collection of the British Museum, giving another locality to the species, and showing how very widely it is distributed in the New World.

Harpiocephalus suillus, Temm.

Add Mount Willis, Java, 2500 feet, to the localities of this species (Baron von Hügel and O. Thomas, Br. Mus.).

Harpiocephalus hilgendorfi.

Harpiocephalus hilgendorfi, Peters, 'M.B. Akad.' Berlin, 1880, p. 24, pl., figs. 1–10.

Ears somewhat shorter than the head, rounded off at the tips, outer margin of the conch flatly emarginate above the middle, the remainder of the outer and inner margin convex. Tragus long, reaching to the edge of the emargination on the outer side, pointed, with a tooth-like lobule at the base of the outer margin, the inner margin convex, the outer concave in upper three-fourths. Nostrils as in *H. harpia*.

Wing-membrane extending to the middle of the first phalanx of the first toe. Extremity of the tail projecting 0·15 inch beyond the interfemoral membrane.

Fur, long and soft, extending thickly upon the interfemoral membrane and upon the backs of the toes; the wing-membrane between the humerus and femur more thinly clothed with long hairs. Muzzle dark-brown, under the eyes and behind the chin greyish-white: on the back greyish-brown, each hair dark at the base with greyish extremity, or with a sub-apical dark band and whiter tip; on the interfemoral membrane lighter brown, almost unicoloured; fur on the abdominal surface shorter, bi-coloured, dark at the base, at the surface greyish-white.

Length (of an adult male): head and body 2″·5 inches, tail 1″·5, head 0″·85, ear 0″·65, tragus 0″·38, forearm 1″·6, thumb 0″·6, third finger (metacarp. 1″·5, 1st ph. 0″·7, 2nd ph. 0″·9), fourth finger (metacarp. 1″·4, 1st ph. 0″·55, 2nd ph. 0″·5), fifth finger (metacarp. 1″·45, 1st ph. 0″·5, 2nd ph. 0″·45), tibia 0″·65, calcaneum 0″·55, foot 0″·48.

Hab. Yedo, Japan. Type in the collection of the Berlin Museum.

With the exception of *H. harpia*, this is the largest known species of the genus. In the synoptical table of the genus ('Catal. Chiropt. B. M.' p. 277), it may be arranged thus:—

I. First upper premolar much smaller than the second	Subg. *Murina*.
a. Upper third of the outer margin of the ear-conch concave, forearm 1″·35 . .	1. *H. suillus*.
b. Upper third of the outer margin of the ear-conch flatly emarginate, forearm 1″·6 .	2. *H. hilgendorfi*.
c. Upper third of the outer margin of the ear-conch convex, forearm 1″·1 . . .	3. *H. auratus*.

Harpiocephalus harpia, Temm.

Add also Mount Willis, Java, to the localities of this species (Hodgson and O. Thomas, Br. Mus.).

Vespertilio capaccinii, Bonap., var. *V. macrodactylus*, Temm.

Dr. W. Peters, who in 1866 demonstrated the identity of Bonaparte's and Temminck's types, having obtained a well-preserved specimen corre-

sponding to the latter from Nikko, Japan, has been enabled to add the following notes[1]:—The European form is larger, has longer feet, broader and more rounded-off ears, and the tragus is distinctly curved outwards above, whereas in the Japan animal it is quite straight.

Vespertilio daubentonii, Leisl.

To synonymy add *Vespertilio pallescens*, Crespon (' Faune Meridionale,' t. i. p. 11, 1844), vide Trouessart, (' Bullet. Soc. Sci. Nat. de Nimes,' fév. 1879, No. 2, p. 35). The same writer has discovered this species in caves near Villevêque, Maine-et-Loire.

Vespertilio bechsteinii, Leisl.

Found in caves, referred to above, with *V. daubentonii* (Trouėssart).

Vespertilio africanus, Dobson.

Owing to a mistake in the labelling of the type, I was led to assign the Gaboon as a locality for this form, the true country of which, Mr. Oldfield Thomas informs me, is unknown. *V. africanus* is easily distinguished from *V. murinus* by its much shorter ears, and acutely pointed tragus, but intermediate forms may, hereafter, turn up, and the name which has been unfortunately given may conveniently sink into the list of synonyms.

Vespertilio nigricans, Wied.

To list of localities add Popayan, New Grenada, and Cordova, Argentine Republic (Göttingen Mus.).

Vespertilio lucifugus, Leconte.

Add Nova Scotia (Matthew Jones and O. Thomas, Br. Mus.).

Kerivoula africana, Dobson.

In my description of this species (' Catal. Chiropt. Br. Mus.,' p. 335), the ears should have been described as being ' as long as the head,' so as to agree with the statement in the synoptical table (*op. cit.* p. 331).

Kerivoula smithii.

Kerivoula smithii, O. Thomas, ' Ann. Mag. Nat. Hist.' August, 1880, p. 338 (with a woodcut of the ear).

Ear-conch as in *K. africana*, but the basal lobule of the tragus is exceedingly small. Wings to the base. Fur, above and beneath, greyish-brown, the extremities of the hairs shining grey. Distribution of the fur as in *K. lanosa*, with the exception of the interfemoral fringe, of which there is no trace.

Inner upper incisors long, with a distinct posterior secondary cusp at the commencement of their terminal third, to which point the extremity of the outer incisor on each side extends; outer incisors with a postero-internal secondary cusp at the commencement of their terminal half; first upper premolar intermediate in size between the second and third, lower premolars equal.

[1] *M. B. Akad. Berlin*, 1880, p. 25.

Length (of the type, an adult male, in alcohol): head and body, 1″·55, tail 1″·7, head 0″·58, ear 0″·55, tragus 0″·3, forearm 1″·3, thumb 0″·27, third finger 2″·7, fifth finger 1″·9, tibia 0″·55, foot 0″·25.

Hab. Old Calabar, West Africa. Type in the collection of the British Museum.

In my synopsis of the species (' Catal. Chiropt. Br. Mus.' p. 331), this species may be arranged as follows:—

γ′. Outer upper incisors unicuspidate, longer than the outer secondary cusps of the inner incisors; forearm 1″·1 . *K. africana.*
δ′. Outer upper incisors bicuspidate, not exceeding the outer secondary cusps of the inner incisors in vertical extent; forearm 1″·3 . . . . *K. smithii.*

Kerivoula javana.

Kerivoula javana, O. Thomas, 'Ann. Mag. Nat. Hist.' June, 1880 (woodcut of head).

Ears rather short, laid forwards they extend about half-way between the eyes and the extremity of the nose; ear-conch and tragus as in *K. jagorii.*

Distribution of the fur as in *K. papuensis*, but there is no interfemoral fringe. Above and beneath greyish black, the proximal third of each hair being black, the middle third whitish, the extremity black occasionally tipped with shining grey.

Teeth as in *K. papuensis.*

Length (of the type, an adult female, in alcohol): head and body 1″·9, tail 1″·7, head 0″·78, ear 0″·6, tragus 0″·37, forearm 1″·53, thumb 0″·27, third finger 3″·0, fifth finger 2″·2, tibia 0″·72, foot 0″·35.

Hab. Kosala, near Bantam, Java (2100 feet); collected by Mr. H. O. Forbes. Type in the collection of the British Museum.

In my synopsis of the species (*l.c.*) this species may be thus arranged:—

η′. Forearms and thumbs naked; fur bicoloured . . . *K. jagorii.*
θ′. Forearms and thumbs clothed with short appressed hairs; fur tricoloured . . . . *K. javana.*

Kerivoula lanosa, Sm.

To the description add:—The second finger, and along the outer margin of the wing to the extremity of the last phalanx of the third finger, as well as the tail, are clothed with short shining yellow hairs. Outer upper incisor with a posterior basal cusp, which in some specimens is quite worn down, and the tooth then appears to be unicuspidate.

Mr. Oldfield Thomas has called my attention to the above omission, which is required in order to make the description agree with the characters given in the synopsis of the species.

Natalus micropus.

Natalus micropus, Dobson, 'P.Z.S.' 1880, p. 443 (woodcut of head).

Ears and tragi as in *N. stramineus*, but the tip of the ear-conch is obtusely rounded off, and the external emargination is very shallow. The superior margin of the face terminates above the nasal apertures in a small rounded wart-like process, covered on all sides, except in front, by thickset hairs, in front naked, with a projecting upper margin. Lower lip

reflected outwards as in *N. stramineus*, but beneath it, in front, there is, as in the species of *Chilonycteris* (*Phyllostomidæ*), but much less developed, a small horizontal cutaneous projection, like a second lower lip.

Wings from the tibiæ, at junction of middle and lower thirds. Foot extremely small, appearing scarcely half the size of that of *N. stramineus*. Fur, above, pale yellowish brown at the base, the terminal half reddish or chestnut brown; beneath, pale yellowish brown throughout. This is the appearance of the fur in alcohol.

Upper incisors like those of *N. stramineus*, but the outer incisor on each side, instead of exceeding the inner in cross-section, is equal to or even smaller than it; upper premolars as in that species, but the second premolar is still more widely separated from the third.

Length (of the type, an adult male): head and body 1″·5, tail 1″·85, head 0″·65, ear 0″·5, forearm 1″·3, thumb 0″·15, third finger (metacarp. 1″·5, 1st ph. 0″·55, 2nd ph. 0″·7), fourth finger (metacarp. 1″·1, 1st ph. 0″·35, 2nd ph. 0″·35), fifth finger (metacarp. 1″·05, 1st ph. 0″·35, 2nd ph. 0″·35), tibia 0″.65, foot 0″·25.

Hab. Jamaica (environs of Kingston).

Natalus lepidus, Gerv., is still smaller, has a differently formed tragus, and is also easily distinguished from both this species and *N. stramineus* by its dentition.[1]

The discovery of this additional form requires a change in the synopsis of the species as given by me at page 342 (*op. cit.*); the species may now be arranged as follows:—

a. Lower premolars equal.
    a′. A horizontal cutaneous expansion beneath the lower lip in front; forearm 1″·3 . . . *N. micropus.*
    b′. No cutaneous expansion; forearm 1″·5 . . *N. stramineus.*
b. First lower premolar half the size of the second.
    c′. No cutaneous expansion; forearm 1″·05 . . *N. lepidus.*

Thyroptera tricolor, Spix.

To localities of this species add Sarayacu, Ecuador (Buckley and O. Thomas).

Myxopoda aurita.

Myxopoda aurita, A. Milne-Edwards, 'Bull. Soc. Philom. de Paris,' June, 1878; Dobson, 'P.Z.S.' 1878, p. 871.

Crown of the head but slightly raised above the face-line; muzzle obliquely truncated, in general form closely resembling that of the species of the genus *Chilonycteris* (*Phyllostomidæ*), for the nostrils open widely apart by similar circular sharply defined margins, and the lower lip is also papillated and reflected outwards, though not so broadly, and it has not a thin free margin; the obtuse extremity of the rather long muzzle projects in front considerably beyond the lower lip. Ears very large, much longer than the head, in general outline like those of *Vespertilio murinus*, but the inner margin of the conch commences in a small lobe projecting downwards; in the usual position of the tragus or slightly in front of it there is an irregularly square lobe continuous above with the keel of the ear-conch; opposite this, on the outer side, is a mushroom-shaped process consisting of a short stalk supporting a broad flat reniform expansion; the outer margin of the conch terminates near the angle of the mouth.

[1] See *Catal. Chiropt. Brit. Mus.* 1878, p. 344.

Thumb with an ill-developed claw, but the whole of the inferior surface of its metacarpal and phalangeal bones supports a large flat horse-shoe-shaped pad, more than 0″·2 inch in diameter, whereof the circular margin is directed forwards and slightly notched in front. The feet have also adhesive cushions, but while resembling those of the thumbs in structure they differ in being much smaller.

Metacarpal bone of the index finger nearly as long as that of the index finger, but there are no distinct phalanges; third finger with *three* phalanges, whereof the first and second are nearly equal in length.

The tail projects beyond the posterior margin of the interfemoral membrane, as in *Thyroptera tricolor*, but to a much greater extent, the free portion being nearly as long as the tibia; calcaneum long, with a very narrow lobe notched or toothed near the foot.

As in *T. tricolor*, the toes are united as far as the base of the claws, and have each two phalanges, and the wing-membrane extends almost to the base of the claws.

Dentition:—inc. $\frac{2-2}{4}$, c. $\frac{1-1}{1-1}$, pm. $\frac{3-3}{3-3}$, m. $\frac{3-3}{3-3}$. Upper incisors short, in pairs, placed close to the canines; the outer incisor, on each side, small, conical, and acutely pointed, but much larger than the inner one, which lies close to it, and can hardly be discerned without a lens; lower incisors short and blunt, in the direction of the jaws; first and second upper premolars very short, the third exceeding the molars in vertical extent; second lower premolar minute, in the tooth-row, the first premolar slightly smaller than the third; molars acutely tubercular, with W-shaped cusps.

Length (of the type, an adult male, in alcohol): head and body 2″·3 inches, tail 1″·9, tail free from membrane 0″·6, head 0″·85, ear 1″·3, tragus 0″·25, forearm 1″·85, thumb 0″·3, third finger (metacarp. 1″·5, 1st ph. 0″·7, 2nd ph. 0″·75, 3rd ph. 0″·55), fifth finger (metacarp. 1″·5, 1st ph. 0″·5, 2nd ph. 0″·5), tibia 0″·7, calcaneum 0″·6, foot 0″·3.

Certain peculiarities in the structure of this very remarkable species recall similar peculiarities in *Thyroptera tricolor*, and have evidently resulted from adaptation to the same purposes. Thus in these two species alone are the toes united to the base of the claws, and in them alone, among all known species of bats (except the *Phyllorhininæ*), have the toes an equal number of phalanges; they also, in the possession of a third phalanx in the middle finger, differ from all the species of *Vespertilionidæ*, and from those of the allied families. This species, however, differs remarkably from *T. tricolor* in the structure of the adhesive disks, in the presence of a well-developed metacarpal bone of the second finger, in the form of the head and ears, and in dentition, and must undoubtedly be considered the type of a distinct genus of *Vespertilionidæ*.

The adhesive cushions of the thumbs and feet are evidently less perfect clinging organs than the corresponding parts in *T. tricolor*; unlike them, the thumb-pads are sessile, scarcely hollow on their inferior surface, and evidently homologous in all respects to those of *Vesperugo pachypus*; but the foot-pads differ from those of that species in being much smaller and in this respect corresponding with *T. tricolor*.

It is probable that this species (in common with the few other known species of bats provided with such accessory clinging organs[1]) uses the

[1] See my paper 'On Peculiar Structures in the Feet of certain Species of Mammals, &c.,' *P.Z.S.*, 1876, p. 526, pl. lv.

adhesive cushions in sustaining its hold on the smooth hard stems and leaves of palms and of other hard-wooded trees.

Miniopterus Schreibersii, Nat.

Lately discovered at Vernet-les-Bains by M. Lataste, and in the Grotto de Sarre (Basses Pyrénées) by M. de Folin,[1] the first recorded occurrence of this species in France. Also obtained at Awa, Japan (Hilgendorf and Peters).

Emballonura semicaudata, Peale.

The British Museum has lately obtained a specimen of this species (hitherto recorded from the Polynesian sub-region only) from Sarawak, collected by Mr. Everett.

Emballonura raffrayana.

Emballonura raffrayana, Dobson, 'P.Z.S.' 1878, p. 876 (with woodcuts of head, ear, and muzzle).

Slightly larger than *E. nigrescens*, and agreeing with that species in the comparatively widely separated nostrils, but resembling the species of the other section of the genus in the projecting extremity of the muzzle, which extends considerably beyond the lower lip; the ears also are much broader, and the upper third of the outer margin of the conch is convex, not concave; the tragus is comparatively shorter and much broader, attaining its greatest breadth above, where it is so broadly rounded off as to appear abruptly truncated; the outer and inner margins are straight or faintly concave.

Wings from the ankles or from the tarsi; feet much larger than in *E. nigrescens*; calcanea about two-thirds the length of the tibiæ; fur above dark brown, paler at the base; beneath, paler throughout, wings nearly naked; upper surface of the interfemoral membrane thinly clothed as far as the extremity of the tail.

Teeth as in *E. nigrescens*, except that the first premolar is smaller and scarcely raised above the level of the gum.

Length (of an adult ♂): head and body 1″·65, tail 0″·5, head 0″·65, ear 0″·58, tragus 0″·2, forearm 1″·55, thumb 0″·25, third finger (metacarp. 1″·3, 1st ph. 0″·4, 2nd ph. 0″65), fourth finger (metacarp. 1″·1, 1st ph. 0″·3, 2nd ph. 0″·2), fifth finger (metacarp. 1″, 1st ph. 0″·38, 2nd ph. 0″·15), tibia 0″·6, calcaneum 0″·45, foot 0″·3.

Hab. Gilolo Island.

Type in the collection of the Paris Museum.

Coleura afra, Peters.

In recording this species from Tschaka, East Africa, Dr. Peters remarks ('M. B. Akad. Berl.,' 1879, p. 832) that, as noted in his original description, there is a groove in the lower lip. To this I can only reply that in the specimen (preserved in alcohol) in the British Museum, from Dr. Peters' collection, there is no trace of a groove in the front of the lower lip.

[1] Trouessart, *Le Naturaliste*, 1879, p. 125.

Taphozous mauritianus, Geoff.

Taphozous dobsoni, Jentink ('Notes from the Leyden Museum,' 1879, p. 123), must be referred to this species. Having suspected from the description that the species, which Dr. Jentink had been good enough to connect my name with, was at most a variety only of *T. mauritianus*, I sent a specimen of that species to the Leyden Museum, and had it compared with the type of *T. dobsoni*. The small fleshy pads at the base of each thumb and on the sole of the foot, noted as a specific peculiarity by the describer, are equally present in all other species of the genus, indeed in the species of most other genera of the family *Emballonuridæ*, being particularly large in the sub-family *Molossinæ*,[1] having reference, I believe, especially to progression on a flat surface, and not coming within the class of accessory clinging organs described by me in my paper referred to by Dr. Jentink.[2]

Taphozous nudiventris, Cretzsch.

Nycticejus serratus, Heuglin ('Reise in Nordost-Afrika,' p. 36, 1877), is evidently a synonym of this species.

Noctilis leporinus, L.

In November last, when dropping down the Sibún river, British Honduras, by moonlight, about 6 p.m., between the tall mangroves which crowd the banks, one of my companions in the boat (Dr. H. A. W. Richardson, R.N.) shot a specimen of this species which was flying about a yard or so above the surface of the smooth stream. The remains of some of the small insects which were disporting themselves over the river were found in his mouth, but the stomach was quite empty. Several specimens of a species of Nycteribia were seen running about on the short fur. It was probably to get rid of such parasites, and not to catch shrimps, that the individuals observed by Mr. Fraser (see 'Catal. Chiropt. B.M.,' p. 397) occasionally struck the water as they flew along.

Rhinopoma microphyllum, Geoff.

Heuglin ('Reise in N.-O. Afrika,' 1877, ii. p. 24) has described as new *Rh. cordofanicum*, which he distinguishes as being larger than this species. The measurements given, however, are considerably less than those of the type of this species, and I have no doubt that this species, as well as those described by him in conjunction with Fitzinger ('Sitzungb. Akad. Wien,' 1866), namely, *Rh. senaarense* and *Rh. longicaudatum*, are also referable to this species.

Nyctinomus bivittatus, Heuglin.

From the description (*op. cit.* p. 28), it would appear to me that the names *Dysopes talpinus* and *hepaticus*, Heuglin, must be considered synonyms of this species, which is so closely related to *N. plicatus* that it can scarcely be regarded as more than a local race of that species.

Nyctinomus brachypterus, Ptrs.

To the localities add Malindi, E. Africa (Fischer and Peters).

[1] See my definition of that sub-family in *Catal. Chiropt. B.M.*, pp. 402, 403.
[2] *Vide supra*, footnote, p. 192.

Nyctinomus limbatus, Ptrs.

Add also Kitui, Ukamba, E. Africa (Fischer and Peters).

Nyctinomus macrotis, Gray.

Specimens of this species taken in Jamaica were found by me in the Kingston Museum. This adds another new mammal to the fauna of the island.

Nyctinomus setiger.

Mormopterus setiger, Peters, 'M.B. Akad. Berl.' 1878, p. 192, pl. i. fig. 2.

Ears triangular, shorter than the head, widely separated from each other; tip of the ear-conch rounded off, the inner and outer margins faintly convex; tragus quadrate, the thickened upper margin with a few hairs; anti-tragus scarcely defined, and not separated by a notch from the outer margin of the conch. Head very flat and broad; muzzle flat above, slightly hollowed in the middle, clothed with short hairs which do not conceal the skin. Nasal apertures obliquely oval, opening under the sharply cut extremity of the muzzle, separated by more than their double diameter from each other. The broad, thickened, but not transversely folded upper lip has on either side four or five rows of short thickened bristles, between which fine long and short hairs project outwards; the lower lip has a few shorter but similar bristles.

Dentition:—inc. $\frac{1-1}{6}$, c. $\frac{1-1}{1-1}$, pm. $\frac{1-1}{2-2}$, m. $\frac{3-3}{3-3}$. Upper incisors distinctly bicuspidate, the outer cusps short; the remaining teeth present no peculiarity.

Fur short; on the back, sides of the neck, thorax, and abdomen reddish-brown, pale at the base of the hairs; middle of the breast and abdomen clothed with still shorter hairs of a reddish-yellow colour. Throat with a transverse fold passing into a sacciform groove.

Tail extending for half its length beyond the interfemoral membrane. Thumbs and toes with a few long bristle-like hairs. Wing-membrane dark-brown.

Length (of a female specimen in alcohol): head and body 2″·5 inches, tail 1″·1, free from membrane 0″·8, ear 0″·65 × 0″·45, tragus 0″·15, fore-arm 1″·4, thumb 0″·23, third finger (metacarp. 1″·4, 1st ph. 0″·55, 2nd ph. 0″·7), fourth finger (metacarp. 1″·3, 1st ph. 0″·5, 2nd ph. 0″·45), fifth finger (metacarp. 1″·0, 1st ph. 0″·3, 2nd ph. 0″·35), tibia 0″·43, calcaneum 0″·65, foot 0″·3.

Hab. Ndi, Taita, East Africa.

Type in the Berlin Museum collected by Herr J. M. Hildebrandt.

This species is easily distinguished from those of the section of the genus to which it belongs by the very widely separated ears and by the form of the tragus.

Family PHYLLOSTOMIDÆ.

Chilonycteris macleayi, Gray.

During a visit to Jamaica in March last, I observed many individuals of this species flying about in the environs of Kingston, about a quarter-of-an-hour after sunset; their flight is remarkably rapid. Thanks to

Mr. Edward Newton, who shot several for me, I was able to examine them in the recent state, and found that in all the fur was tinged with reddish-yellow, a colour never observed by me in dried skins.

Mormops blainvillei, Leach.

This remarkable species also occurs in the environs of Kingston, and a specimen with exceedingly brilliantly coloured fur of a golden chestnut hue was shot by Mr. Newton.

Lonchorhina aurita, Tomes.

The British Museum has lately received a specimen of this extraordinary species from New Granada, collected by Mr. Fry. Hitherto the species was represented by a single specimen, the type in the collection of the museum of the Army Medical Department, of which the locality was uncertain, but from collateral evidence, believed by me to be Trinidad, a supposition now rendered extremely probable. This second specimen differs in no important respect from the type.

Schizostoma megalotis, Gray.

To the localities of this species add Popayan, New Granada.

Lonchoglossa wiedii, Ptrs.

In an apparently adult male specimen from Popayan, I found the zygomatic arches cartilaginous. The following are the measurements:—Length: head and body 2″·5 inches, head 1″·1, tail 0″·15, ear 0″·6, forearm 1″·6, thumb 0″·35, third finger (metacarp. 1″·5, 1st ph. 0″·5, 2nd ph. 0″·8, 3rd ph. 0·5), fourth finger (metacarp, 1″·45, 1st ph. 0″·4, 2nd ph. 0″·55), fifth finger (metacarp. 1″·25, 1st ph. 0″·35, 2nd ph. 0″57), tibia 0″·55, foot 0″·38.

Chœronycteris minor, Ptrs.

To the localities of this species add Guatemala (Godman).

Artibeus bilobatus, Ptrs.

Add Sarayacu, Ecuador, as a locality (O. Thomas).

Artibeus perspicillatus, L.

This appears to be by far the commonest species of bat in Jamaica. I found it abundant in every cave visited by me, inhabiting the honeycomb-like cells in the white limestone. The floor of these caves is covered to the depth of many feet with their dung, which forms a soft black mass, in which near the entrances a few sickly plants of the bread-nut were always found vegetating, having sprung up from the rejected kernels of that fruit, which appears to form the greater part of their food. At King's House, near Kingston, Mr. Newton pointed out to me on the floor of the bath-room the remains of these fruits, which the bats carried in at night-time, to feed upon at leisure, while they hung themselves from the rafters. At the same place, about midday, we forced an individual to quit his home in a hollow mango tree, but he flew only as far as the next tree, where he was soon secured. In him the fur was strongly tinged

with yellow, over the shoulder especially, so that when flying forth from his retreat I thought it was a specimen of *Noctilio leporinus.* In this respect this individual contrasted remarkably with all the cave-haunting specimens I had examined, for in them the colour of the fur appeared to be almost quite uniform, namely, dark brown in the terminal third, the extreme tips of the hairs greyish, the basal three-fourths pale greyish brown; beneath the greater part of the hairs unicoloured greyish brown, paler towards the extremities. The facial streaks were more or less defined in all the individuals captured by me.

Artibeus quadrivittatus, Ptrs.

Add Popayan to the localities of this species.

Chiroderma salvini, Dobson.

An adult male specimen, also from Popayan, in the collection of the Göttingen Museum, has the facial streaks faintly marked, thus showing that the development of these marks are probably as variable as I have already noticed in the case of *Artibeus planirostris.* There is also a very faint white line along the spine, which is absent in the type. The peculiar form of the first lower premolar is, however, as well marked as in the type.

Preliminary Report of the Committee, consisting of Professor W. E. AYRTON (*Secretary*), Dr. O. J. LODGE, Mr. J. E. H. GORDON, *and* Mr. J. PERRY, *appointed for the purpose of accurately measuring the specific inductive capacity of a good Sprengel Vacuum, and the specific resistance of gases at different pressures.*

IN 1876 two of the members of your present Committee concluded, from theoretical reasons, based on the analogy between the viscous yielding of bodies to mechanical stress and the absorption of the electric charge in a Leyden jar, that some connection of an inverse order would be found to exist between the specific inductive capacities and the specific resistances of dielectrics. As at that time it was only for gutta percha and india-rubber that the specific resistances had been measured, it was necessary, in order to put the theory to the test of experiment, to carefully measure the specific resistances of several other dielectrics of which the specific inductive capacities were known. The substances selected were paraffin-wax, shell lac, mica, ebonite, &c., and it was found that, in a general way, if bodies were arranged in increasing order of specific inductive capacity, they would be found arranged in decreasing order of specific resistance.[1]

Again, since different gases had different indices of refraction for light, it was felt that Faraday's not having succeeded in finding experimentally different specific inductive capacities for the various gases, must have arisen from the comparative roughness of his apparatus; and very delicate experiments undertaken in consequence, showed that hydrogen had a decidedly less specific inductive capacity than air, and that carbonic

[1] 'The Viscosity of Dielectrics,' by W. E. Ayrton and John Perry, *Proc. Roy. Soc.* No. 186, 1878.

dioxide, coal gas, sulphuric dioxide, &c., a decidedly greater. Lastly, since the resistance of a gas to disruptive discharge varied with the pressure, it was anticipated—also in opposition to the results of Faraday's experiments—that the specific inductive capacity of even the vacuum of an ordinary air-pump must be slightly different from unity, a conclusion also subsequently verified by experiment.[1]

The method employed for that investigation which was carried out in Japan consisted in using two condensers, one an open air condenser of adjustable capacity, the other a closed condenser into which any gas at any pressure could be put. The open air condenser was adjusted to have the same capacity as the closed one when the latter was filled with air at the ordinary pressure and temperature; then the change in capacity of the latter when the pressure of the air inside was diminished, or when another gas was introduced, could be determined by changing the insulated coatings of these two condensers to equal and opposite potentials, discharging them into one another, and measuring the resultant potential with a Thomson's quadrant electrometer adjusted for great sensibility.

Previously, however, to this, but quite unknown to these members of your Committee, Prof. Boltzmann had made a similar investigation, using, however, a different method of experimenting. The results obtained in the two independent investigations for the same gases are placed underneath side by side, and the fairly close agreement, considering the extreme delicacy of the experiments, make it quite certain that the general bearing of the experiments is correct:—

	Ayrton and Perry	Boltzmann
Air	1·0000	1·0000
Vacuum	0·9985	0·9994
Hydrogen	0·9998	0·9997
Coal Gas	1·0004	
Marsh Gas		1·0004
Carbonic dioxide	1·0008	1·0004
Sulphuric dioxide	1·0037	

The gases were at 760 mm. pressure; the vacuum varied from about 10 mm. to somewhat greater pressures. The observation for sulphuric dioxide is given, as it is the highest specific inductive capacity yet obtained for any gas.

The very peculiar behaviour of a good Sprengel vacuum in resisting the passage of an induction spark led to the formation of this Committee, to investigate, with the aid of a grant from the Association, the specific inductive capacity of a far higher vacuum than had been employed in either of the two preceding investigations since Messrs. Ayrton and Perry predicted that such a vacuous space would be found to have a capacity very considerably smaller than if filled with ordinary air.

The closed condenser in this case consists of five aluminium cylinders 39·3 centimètres long, placed concentrically at about $\frac{1}{3}$ centimètre apart, in a glass tube 58·5 centimètres long and 5·5 centimètres in diameter. The second and fourth cylinders form the insulated coating, and the first, third, and fifth the earth coating. The cylinders comprising each coating are rigidly connected at each end with a thin platinum rod, and these platinum rods, like the cylinders, do not touch the glass tube, but are held in position by a thin glass rod, one end of which is fused to the platinum

[1] 'On the Specific Inductive Capacity of Gases,' by John Perry and W. E. Ayrton, *Trans. Asiatic Soc.* of Japan, Vol. v. part i. p. 116.

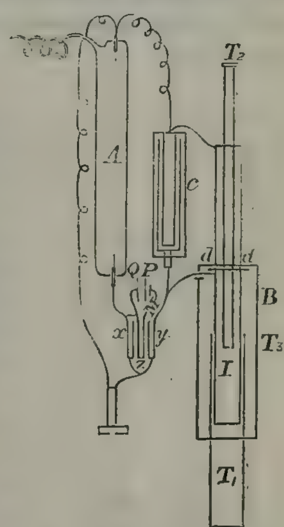
rod and the other to the inside of the glass tube. To give, in a small space, length to these glass rods, for obtaining surface insulation, they are made zigzag, and in the form of a flat spiral. To the thin platinum rods are attached two fine platinum wires, which form the two electrodes of the condenser, and where these pass out through the glass tube, glass is fused on to the wire both inside and outside, as in the figure, to increase the surface insulation.

The area that one set of aluminium cylinders exposes to the other is about 1800 square centimètres, so that the electrostatic capacity is about 450 centimètres in absolute units, or $\frac{1}{2000}$ of a microfarad.

End of Condenser.

A small spiral glass tube connects the condenser with a three-fall-tube Sprengel pump, and as the internal capacity of the condenser is large, it was thought desirable to attach to the pump an Alvergniat or Geissler arrangement to enable the pressure to be rapidly reduced to about 10 centimètres of mercury. A barometer gauge and a McLeod gauge are attached to the pump. The entire glasswork in the apparatus was made by Mr. Gimingham, and the Committee desire to express their thanks for the assistance he has so kindly given.

Method of Experimenting.—In the accompanying figure, A is the aluminium condenser just described, the interior not being shown in the figure; B is Sir William Thomson's 'sliding condenser,' kindly lent by him to the Committee. This, as is well known, consists of a brass tube, I, about 38 centimètres long and 5·08 centimètres in external diameter, attached at one end to an ebonite collar, $d\,d$, by which it is supported and insulated. Outside and inside this brass tube, but without touching it, slide two other tubes, T_1 and T_2, electrically connected with the outer tube T_3 and with the earth. The motion of the tube T_1 forms a coarse adjustment, and that of the tube T_2 a fine adjustment of the capacity of the condenser. On account of the action of the edges it would be somewhat difficult to calculate the whole capacity of this condenser for any given position of the tubes, but it is comparatively easy to calculate the change of capacity produced by moving either tube a known distance measured on the fine linear scale engraved on each of the sliding tubes.



As the capacity of this condenser, when the tube T_1 is in its mean position, is considerably less than that of the aluminium condenser, another air-condenser, C, having a fixed capacity about equal to the difference, was constructed. B, then, could be adjusted so that its capacity, together with that of C, was equal to that of A, when A contained air at ordinary pressure. Then any change in the capacity of A, produced by exhausting the air, could be measured by finding the new adjustment of B necessary to produce balance.

The mode of testing the equality of capacities was suggested by one of the Committee, Dr. Lodge, and consisted of a modification of Prof. Hughes' Induction Balance. Z is a coil of wire of about 3 ohms' resistance, in which the current from two or three Grove's cells, P, flows in-

termittently, the circuit being alternately made and broken by a clock, *M*. *x*, *y* are perfectly similar coils of about 800 ohms' resistance each, and adjusted in position relatively to *Z*, so that when the condensers on the two sides of the balance have perfectly equal capacity no sound is heard in an especially delicate telephone, *T*, when the connections are made as in the figure. It will be observed that the nature of the arrangement is such that any failure of insulation in *A* would make it appear to have too large a capacity and not too small, as would be the case with the method of experimenting previously described.

For air at pressures greater than one millimètre, the Committee have not thought it necessary to make many experiments, but between 0·01 and 0·001 of a millimètre pressure several sets of experiments have been carried out. At the latter pressure—that is, at about one-millionth of an atmosphere—the specific inductive capacity is certainly low, some experiments apparently making it as much as 0·6 to 0·8 per cent. less than that for ordinary air, whereas the greatest diminution obtained for an air-vacuum in the two previous investigations, when the pressure was not diminished lower than 5 millimètres, was only 0·1 per cent. In all the sets of experiments for very low pressures there are decided waves in the curves connecting capacity and pressure, but whether these waves really express a physical law, or whether they are due to the method of experimenting with currents of very short duration, or whether, lastly, they are due to the capacity not depending solely on the pressure, but also on the amount of residual gas occluded in the aliminium cylinders, the Committee have not yet ascertained, and therefore in this preliminary report they refrain from giving the curves. A sample of the observations, however, may be interesting:—

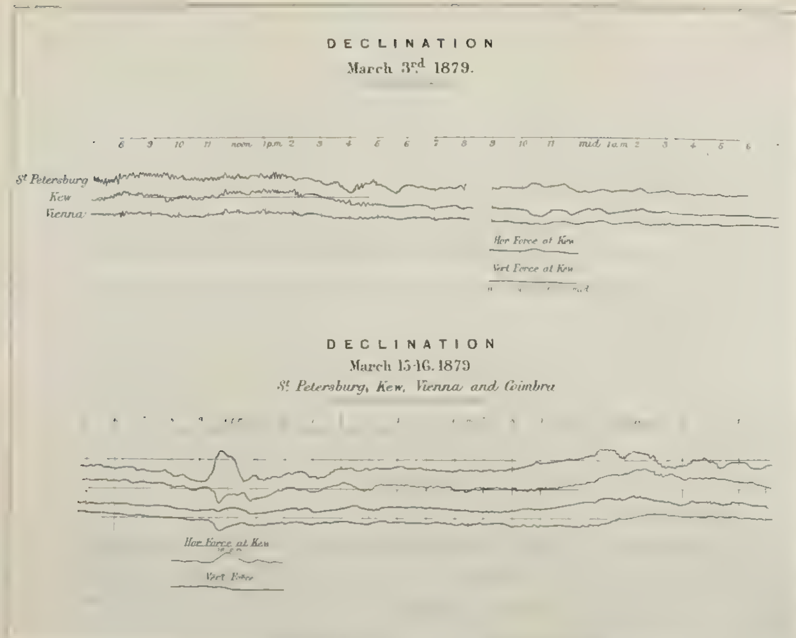
August 26.

	Pressure in millimètres	Reading on small sliding cylinder, T_2, T_1, remaining stationary
Pump continuously working	0·0100	185
	0·0041	194
	0·0031	165
	0·0032	208
	0·0020	162
	0·0017	140
	0·0020	160
	0·0018	142

August 28.

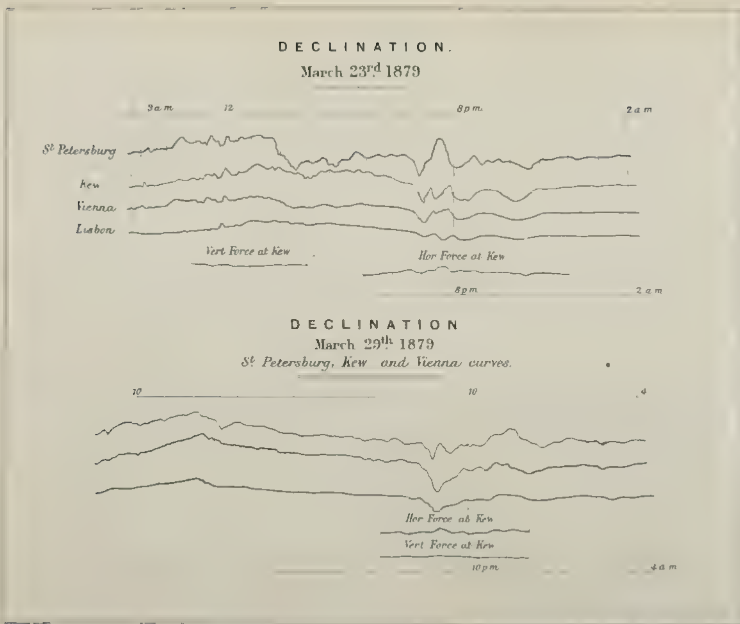
	Pressure in millimètres	Reading
Air being very slowly let in	0·0207	314
	0·0407	332
	0·0568	343
	0·0765	350
	0·1204	326
	0·1924	292
	1·0000	320
	3·2500	341
	5·5000	379
	760·0000	395

The readings on either day may be compared one with another, but not those on different days. In either case, however, a difference of 100 in the reading indicates roughly a difference of about 1 per cent. in the capacity of the aliminium condenser. It will be observed that, in addition to the curious fluctuations in the capacity for the same small pressure, a



Illustrating Professor W. Grylls Adams' Communication

Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St Petersburg.

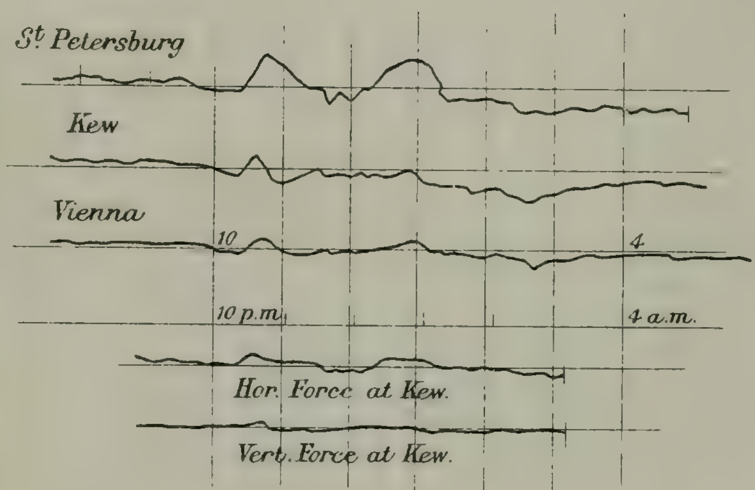


Illustrating Professor W. Grylls Adams' Communication

Comparison of Curves of the Declination Magnetographs at Kew Stonyhurst, Coimbra, Lisbon, Vienna, and St Petersburg.

DECLINATION.

March 28-29 1879.



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Illustrating Professor W. Grylls Adams' Communication.

Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St Petersburg.

result constantly obtained when very small pressures were employed, and which may have arisen from the effect of the remanent occluded gas, there also appears to be a sudden diminution of the capacity at about 0·19 millimètre pressure. To make sure that this was not an accidental result, the air was pumped out again when the pressure was about 3 millimètres until it was reduced again to about 0·1 millimètre, when the same diminution of capacity at about 0·19 was again observed. Now although these numbers are merely now given as a preliminary indication of the results obtained by the Committee, there is this interest about them, as has been pointed out by Mr. G. F. Fitzgerald of Dublin, that the values obtained for the capacity between about 0·02 and 0·2 millimètre's pressure bear a general resemblance to those obtained for the Crookes' force.

One difficulty met with in the investigation consists in an apparent change in the capacity of the condensers B and C (partly, no doubt, arising from changes of temperature) from day to day. A similar difficulty was met with in the previous investigation made in Japan, but it was overcome by making alternate measurements of the capacity of the closed condenser, first with air, then with vacuum, then with air, &c., &c. In the present case this is, of course, impossible, since on account of the large internal capacity of the condenser A, and the considerable quantity of gas occluded in so large a mass of aluminium, it takes several days to obtain a vacuum of 0·001 of a millimètre even, although, at the suggestion of Mr. Gimingham, induction sparks from a large induction coil (not shown in the figure), are kept passing between the two sets of aluminium cylinders at all times that a measurement of capacity is not being made. Probably the best method of procedure is that followed on August 28, the last day of the investigation, viz., first obtain slowly a very perfect vacuum, no measurements of capacity being necessarily made, then admit into the pump, drop by drop, mercury, occluding air, and make, during a couple of hours or so, a complete series of measurements of capacity as the pressure rises from, say, 0·001 of a millimètre up to ordinary atmospheric pressure. Such a set of experiments being performed several times would probably give a fair indication of the curve for capacity. As it is also extremely desirable that the experiments should be made with *statical* charges of electricity, the Committee have had constructed a somewhat modified form of Thomson's quadrant electrometer, which they also propose employing for the measurement of the specific resistance of gas at different pressures—the second half of their work, which they have not yet commenced.

Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg. By Professor W. Grylls Adams, *F.R.S.*

[Plates VII., VIII., and IX.]

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

During the month of March, 1879, there were several very considerable magnetic disturbances, and therefore there were several favourable opportunities for comparing the effects of magnetic disturbances at different

stations wherever photographic records similar to those at Kew are obtained.

Mr. Whipple was accordingly instructed by the Kew Committee to write to the various observatories where declination magnetographs are photographed, to ask that *fac-similes* of the records taken at those stations might be sent to the Kew Committee for comparison.

In answer to this request, Dr. Hann, Director of the Observatory at Vienna, and Senhor Capello, Director of the Observatory at Lisbon, have kindly lent the original negatives, and Rev. Prof. S. J. Perry, Director of the Observatory at Stonyhurst, and Dr. Da Souza, Director of the Observatory at Coimbra, have kindly forwarded positives printed from their original curves, and Dr. Wild, Director of the St. Petersburg Observatory, has kindly forwarded very careful tracings of the St. Petersburg photographs. These have been compared with one another, and with the original negatives taken at the Kew Observatory, and much valuable information has already been obtained. Other records have been asked, but a sufficient time has not yet elapsed for them to come to hand; it is hoped that, as soon as they arrive, a complete discussion of them will greatly extend our knowledge as to the causes of magnetic disturbances over a considerable area of the earth's surface.

A disturbance began at 4.20 a.m., Greenwich time, on the 3rd of March, 1879, which is described in the Stonyhurst record as 'a tremulous motion of the declination magnet, which lasted for about thirteen hours, accompanied by a gradual increase of westerly declination.'

About 5.30 a.m. the agitations west and east became greater, and at 7.30 a.m. there were sudden and great disturbances, the maximum westerly declination being reached about 8 a.m.: again marked disturbances, not quite so sudden, occurred just before 10 o'clock; then, after a slight motion eastward until 10.30 a.m., there was again an increase in the westerly declination, accompanied by great agitations, until 1 p.m., after which there is a decrease in the westerly declination, and the disturbance ends at about 5 p.m.

During the whole time of this increase in the westerly declination the agitations of the declination needle, including some twenty-four maxima and minima values, are absolutely coincident in time, and very often equal in magnitude, at Kew and at St. Petersburg.

At Stonyhurst also the curves are coincident with those at Kew and are almost *fac-similes* of them.

On comparing the photographs at Coimbra and at Lisbon with those at Kew and at St. Petersburg, it is found that the agitations in Portugal are not so clearly marked, but are coincident in time with those at the other stations.

Comparing the Vienna photographs of the same disturbance with those at Kew, they are found to be almost *fac-similes* of one another—every agitation westward or eastward at one place is coincident in time with a similar agitation at the other. The Vienna photographs are remarkably clear, but the agitations are usually not so large as those at Kew, and both are usually less than those at St. Petersburg, as given by the tracings; but the forms and periods of the successive agitations in a disturbance, as well as the duration of the disturbances, are the same at all the stations.

Between 5 and 6 p.m. on the 3rd there was a disturbance, first eastward and then westward, at St. Petersburg, which was not felt at Kew;

and between 10 p.m. and 12 there were simultaneous disturbances at Kew and St. Petersburg, but in opposite directions.

From about 10 to 10.40 p.m. there is a disturbance of a very regular kind, *i.e.* without much agitation, consisting of a motion of the needle towards the *east*, followed by a motion of the needle westward for about half an hour. This disturbance is strongly marked at Kew and at Stonyhurst; is less strongly marked, but coincident in time, at Coimbra and at Lisbon; and also very well shown, but is small, in the Vienna photographs; but in the tracing from St. Petersburg a disturbance begins at the same point of absolute time (*i.e.* about 10 p.m. Greenwich time), with a motion of the needle towards the *west*—this motion westward lasts for about 20 minutes, until 10.20 p.m., and is then followed by a gradual motion eastward until about 10.45 p.m.

The declination at St. Petersburg then remains nearly steady for a quarter of an hour, whilst the westerly declination at the other stations is regularly increasing, and from 11.30 p.m. (Greenwich time) the disturbances at St. Petersburg coincide in direction and in time with those at Kew and at the other stations.

Plate VII., fig. 1, represents the St. Petersburg, Kew, and Vienna declination curves for March 3rd, the time being Greenwich mean time for all stations.

On referring to the Kew curves for the horizontal force, of which Mr. Whipple has kindly prepared tracings for me, I find that whenever the deflections of the declination needle are eastward at Kew and westward at St. Petersburg at the same instant, as in this disturbance between 10 and 10.20 p.m., there is at the same time an *increase* in the horizontal force; and when the deflections are westward at Kew and eastward at St. Petersburg at the same instant, as between 10.20 p.m. and 10.45 p.m., there is at the same time a decrease going on in the horizontal force.

This statement is borne out by the comparisons of disturbances on other days throughout the month.

Three easterly movements of the needle occurred between 3 and 8 p.m. on the 5th of March.

One began about 2.45 p.m., which is only just noticeable at Lisbon and Coimbra when looked for, but which is clearly seen in the Kew and Stonyhurst photographs, and becomes much more important at Vienna, and is much larger still at St. Petersburg; but at all places the greatest easterly declination occurs at the same absolute time (at about 3 p.m. Greenwich time), and there is then an increase in the westerly declination until about 3.30 p.m.

From 5 p.m. to 5.20 p.m. there is an easterly movement of the needle, which is absolutely coincident in time and is well marked at all the stations, and the amount of the disturbance is as great at Kew and at Stonyhurst as it is at St. Petersburg. This is followed by a westerly movement, which is also precisely similar at all the places.

Another similar easterly movement begins about 6.20 p.m. (Greenwich time) at all the stations, and lasts for a quarter of an hour, followed by an equal movement westward for the next quarter of an hour, thus forming a regular V in the photographic curves. The second side of this V is continued to double the length in the St. Petersburg tracings, but the following greatest eastward declination is reached at

the same time (about 7.20 p.m.) at all the stations. Then the needle gradually returns to the westward, and the disturbance dies away.

This deviation of the St. Petersburg curves from the others occurs at 6.40 p.m., at which time there is a sudden increase in the horizontal force.

Another considerable disturbance, consisting of a general eastward movement of the north end of the needle, began about 6 p.m. on the 7th, followed by a westward movement, which ceased about 10 p.m.

In this disturbance, as in others, the Lisbon and Coimbra curves are like exact reproductions of one another, so also are the Kew and Stonyhurst curves. Placing the Lisbon negative behind the Coimbra positive, the dark lines of the Lisbon photograph are seen through the bright lines of the Coimbra curves; and in the same way, placing the Kew negative behind the Stonyhurst positive, the dark lines of the Kew curves are seen to coincide with the bright lines of the Stonyhurst curves, just as if one were an exact print taken from the other.

Comparing the Kew and the Vienna curves this disturbance is found to be of precisely the same character at both stations, but its range at Vienna is less than at Kew. In this case the periods of the disturbance occur at the same absolute time at all the stations.

At St. Petersburg the disturbance at the beginning is also similar in character to that at Kew, but previously at 2 p.m. (Greenwich time), there had been an easterly disturbance at St. Petersburg, which was not perceived at Kew; and just before 8 p.m., towards the end of the great disturbance, the westerly range of the needle is very much greater at St. Petersburg than at Kew, but the needle reaches its extreme positions either west or east exactly at the same absolute time at the two, and, indeed, at all the stations.

Unfortunately at Coimbra four curves are drawn on the same slip, and the zero line for one curve frequently runs into and coincides with the curve for another day, so that it is difficult or impossible to make out the character of the disturbances. The distance between the curve and the zero line appears to be the same as in the Kew curves.

At Stonyhurst three curves are photographed on the same slip, but the difficulty of dealing with the Coimbra curves is avoided by placing the zero or time line a long way from its own curve, but the curves for different days are placed so close to one another that occasionally they are apt to run into and confuse or cross one another.

At Kew, at Lisbon, and at St. Petersburg, two curves are drawn on the same slip, and sufficiently far apart not to interfere with one another, the distance at St. Petersburg being greater than at Kew, because, as a rule, the disturbances are of larger amount than at Kew.

At Vienna each curve is photographed on a separate slip, and the hours are numbered astronomically from 0 to 23, the slip being changed at or just before 21 hr., or 9 a.m. local time, *i.e.* about 8 a.m. Greenwich time.

The Vienna plan of photographing each curve on a separate sheet is the most convenient of all for the comparison of disturbances at different places, and there is an additional advantage in this plan because when there are two or more curves on a slip, disturbances occurring at the same hour on two successive days are not vertically above one another, and the want of agreement of the time lines for two or more curves is apt to be confusing.

From the Stonyhurst report we find that 'the chief disturbance of the month began about noon on the 9th, and lasted till 4 a.m. on the following day.'

On comparing the Lisbon and Coimbra curves for the whole period of this disturbance, they are found to be absolutely coincident throughout.

On comparing the Kew and Stonyhurst curves, they are also found to be absolutely coincident, both in range of disturbances and in time; indeed, this is one of the most remarkable instances that I have seen.

At Vienna the disturbances are nearly all of the same character, and take place at the same time, but the range is not quite so great.

On comparing the St. Petersburg curves, it is found that there are disturbances of the same character, and taking place—*i.e.* having their maxima and minima—at the same time as those at Kew and Vienna and the other stations; but superposed upon these are other disturbances, one to the eastward from 2 to 3.20 p.m., and to the westward from 3.20 to 3.40 p.m.; another violent one to the eastward from 4.20 to 4.50 p.m., followed by a quicker return to the westward until 5 p.m.; another, not quite so violent, eastward from 6 to 6.30, and westward from 6.30 to 7 p.m.; then, after a period of comparative rest, at 10.20 there is another disturbance westward for about ten minutes, followed by a return of the needle to the eastward until 11 p.m., superposed on those disturbances which are the same as the disturbances which are seen in the Kew curves.

The effect of these extra disturbances, which are so marked at St. Petersburg, is only just seen in the Vienna curves, the result being that the heights of some of the maxima are diminished or increased, or the slopes of parts of the curves are slightly altered, in consequence of the action of opposing or reinforcing disturbances.

These differences in the disturbances at St. Petersburg and at the other stations coincide in time with corresponding changes in the value of the horizontal force, as measured by the Kew curves. Thus from 2 to 3.20 p.m. the horizontal force is diminishing, then from 3.20 to 3.40 p.m. the horizontal force is increasing; from about 4.15 to 4.45 p.m. the horizontal force is diminishing, but again increases more rapidly until 5 p.m.; then from 6 to 6.20 p.m. it diminishes, and afterwards increases more slowly until a little after 7 p.m.; after a period of rest there is a large increase from 10.15 to 10.35, followed by a diminution of the horizontal force until 11 p.m.

It thus appears from these comparisons—and the statements are fully borne out by the other principal disturbances which have been examined—that:

A diminution in the horizontal force is accompanied by greater easterly deflections of the declination needle at St. Petersburg than at Kew.
2. Increase of the horizontal force is accompanied by greater westerly deflections at St. Petersburg than at Kew, or is sometimes accompanied by a westerly deflection at St. Petersburg and an easterly deflection at Kew.

On March 11, a disturbance, first eastward for a quarter of an hour until 9 p.m., then westward for an hour, causes a well-marked and regular depression in the declination curve.

This takes place at the same instant at Kew, Stonyhurst, and Vienna, but is not present at St. Petersburg; but at the time of the greatest eastward deflection, at 9.4 p.m., there is a slight westward deflection at

St. Petersburg, the other small disturbances at all the places being the same.

Again, on the 13th, there is a magnetic storm, lasting from 6.20 p.m. until 8 p.m., which takes place absolutely at the same time at all the stations, and for which the curves for places near together absolutely fit one another.

At St. Petersburg this storm was more violent than at the other stations, and was preceded by a violent storm, in which the needle deviated first to the east and then to the west, between 4.20 and 6 p.m. This preceding storm was only slightly felt at the other stations, and rather more at Vienna than at Kew or Stonyhurst.

About 2.30 a.m. on the 14th, there is a sudden disturbance of the needle to the westward. which is stronger at Kew and Stonyhurst than at Vienna or at St. Petersburg.

The next considerable disturbance was on the 15th, beginning at 9.20 p.m. and ending at midnight, followed by lesser disturbances arising from a distinct cause which lasted until 4 a.m. on the 16th.

This disturbance from 9.20 p.m. to midnight produced similar deflections at Kew and Stonyhurst, and also at Coimbra and Lisbon, first rapidly to the east until 9.50 and then to the west; but the range was not so great at these latter places. At St. Petersburg the deflections of the needle were in the opposite direction to those at Kew and Stonyhurst, and the opposite deflections occurred at the same time; and this remark applies to all the oscillations of the declination needle up to midnight. The disturbance westward was also much greater than the simultaneous eastward disturbance at Kew.

The disturbances between midnight and 4 a.m. take place at the same time at all the stations, and are precisely similar in character and in direction at St. Petersburg, at Vienna, and at Kew. They are also equal in amount, so that the curves almost fit one another. Here, then, we have a cause producing opposite disturbances at Kew and at St. Petersburg for more than two hours, followed by probably some other cause of disturbance producing identical effects at all the stations for a period of four hours.

At Vienna from 9.20 to midnight the disturbances were simultaneously in the same direction as, but were very weak in comparison with, those at St. Petersburg, so that this magnetic storm was very little felt at Vienna.

On reversing the Kew curve for this disturbance and comparing it with St. Petersburg, it is seen that the successive maxima and minima are absolutely simultaneous, so that the deflections opposite ways at the two places are seen to be due to the same cause; and the Vienna curve is very nearly coincident with the mean curve obtained by superposing the Kew and St. Petersburg curves.

Plate VII., fig. 2, represents the St. Petersburg, Kew, Vienna, and Coimbra declination curves for March 15th–16th.

The beginning of this disturbance was accompanied by a sudden and large increase of the horizontal force until 9.50 p.m., and then by a diminution until 10.45 p.m., followed by slight oscillations of the needle until midnight, which are simultaneous with the oscillations of the St. Petersburg declination needle.

The vertical force gradually diminishes from 9.20 to 10.30 p.m.

Nothing can show more clearly than this the direct relation between

the changes in the horizontal force and the differences in the declination curves at St. Petersburg and at Kew.

At 11.45 a.m. on March 18 there is a sudden kick to the westward, lasting for about two minutes and measured by a length of 2 millimètres on the Kew curve, *i.e.* giving a deflection of about 2′. This kick takes place simultaneously at St. Petersburg and at Vienna, and is nearly equal at all the stations. It is also felt at the same instant at Coimbra and at Lisbon.

A similar kick, but less marked at St. Petersburg, occurs next day at 11.30 a.m. (Greenwich time) at all the stations.

After an entire agreement between the curves through the day, at 10 p.m. a disturbance occurs which deflects the needle eastward at Kew and westward at St. Petersburg, but by midnight the curves coincide again, and remain coincident with the same very small variations through the night.

Between 3 and 4 p.m. on March 20 we get disturbances opposite ways, first westward at Kew and eastward at St. Petersburg simultaneously, again followed by coincidences through the day.

Another disturbance commenced by a tremulous motion of the magnet about 7 a.m. on the 23rd, and lasted until 11 p.m.

From the beginning of this storm until 1.45 p.m. the several east and west disturbances or oscillations of the needle are simultaneous and of the same character, and are very nearly equal in amount at Kew, Stonyhurst, and at St. Petersburg. From 1.45 to 2.30 p.m. the deflections to the eastward were far greater at St. Petersburg than at the other stations, but were still simultaneous at all the stations. The record at Stonyhurst shows that the vertical force increased in value about 2 p.m., so that here an increase in the vertical force is accompanied by greater eastward deflections at St. Petersburg.

The St. Petersburg curve remains below the Kew and Stonyhurst curves, with the same smaller disturbances, until 7.12 p.m., just after one but before another violent disturbance, each of which lasted half an hour. The first of these two violent disturbances was first eastward and then westward at all stations, but greater at St. Petersburg than at Kew, and was accompanied by a corresponding decrease, and then an increase of the horizontal force. At 7.25 p.m., according to the Stonyhurst record, the V.F. had diminished to its mean value, and simultaneously with this diminution the horizontal force had been increasing. The second violent disturbance was westward at St. Petersburg, and eastward at Kew and Stonyhurst. This second disturbance was also westward at Vienna, but less violent in character. The maximum was reached at 7.30 p.m.

The simultaneous disturbances become alike again in character and direction at 7.50 p.m., but from 8.15 p.m. until 11 p.m. (the end of the storm) the disturbances at Kew and at St. Petersburg do not correspond, but are at times in opposite directions. From 11 p.m. the curves are again agreeing with one another.

The time scales for different stations are nearly but not quite the same; the St. Petersburg is slightly shorter than the Kew scale, and the Kew is slightly shorter than the Vienna scale. They are so nearly equal that for short lengths the difference is not perceptible. In Plate VIII., fig. 1, where the disturbances during seventeen hours on March 23–24 are represented in one diagram, an attempt has been made to guide the eye by

drawing three oblique time lines at 9 a.m., 8 p.m., and 2 a.m. through the St. Petersburg, Kew, and Vienna curves. There is more difficulty in determining the exact instant at which any small disturbance occurs from the Lisbon photographs, as the curves are not divided into hourly or two-hourly divisions as at the other observatories.

From 7.20 to 7.30 p.m. there is a sudden and large increase in the horizontal force, which continues high until 7.40, and then suddenly diminishes until nearly 8 p.m.

On March 28, at 4.30 p.m., a slight eastward disturbance takes place at St. Petersburg, which is scarcely perceived elsewhere. From 10.20 to 10.30 at all the stations the declination needle is moving westward, and both the horizontal and vertical forces at Kew are increasing. From 10.30 to 10.40 the St. Petersburg needle continues to move westward, and the horizontal and vertical forces continue to increase, but the Kew needle moves back to the eastward from 10.30 p.m. until 11.5 p.m., and then westward to 11.30 p.m. From 10.20 p.m. to 1.25 a.m. on the 29th, during which time there are two large disturbances, there is a very close resemblance between the St. Petersburg declination curve and the Kew horizontal force curve, the disturbances being simultaneous, and a westerly deflection at St. Petersburg corresponding to an increase of the horizontal force at Kew. Taking the mean line of no disturbance as common to the two, the height or depth of the Kew horizontal force curve is about one-third of the height or depth of the St. Petersburg declination curve at the same point.

Plate IX. gives the St. Petersburg, Kew, and Vienna declination curves and the horizontal and vertical force at Kew from 10 p.m. to 4 a.m. on March 28–29.

The Vienna curve is very nearly the mean between the St. Petersburg and Kew declination curves between 10.30 and 11.30 p.m., but agrees absolutely with the Kew curve for the part of the disturbance after midnight.

This disturbance was only slightly felt at Lisbon or at Coimbra.

According to the Stonyhurst record, the horizontal force magnet was rather disturbed during these declination disturbances.

On the next day (March 29), at 8.20 p.m., an easterly excursion begins, which is identical at all stations until 8.45 p.m.; but at this point the St. Petersburg needle turns sharply back to the west, while the Kew and Stonyhurst needles continue moving to the east, giving the greatest eastern deflection for the month (15′ 49″). This point is reached at 8.55 p.m., whilst the corresponding western deflection at St. Petersburg is reached about 9.5 p.m. The St. Petersburg curve then falls again, reaching its lowest point at 9.30 p.m., after which the curves show a westward motion of the needles at all stations.

In Plate VIII., fig. 2, the time lines are drawn obliquely, as in the curve for March 23–24.

The Vienna curve is almost exactly the mean of the other two curves, and the Lisbon and Coimbra curves very closely resemble the Vienna curve for this disturbance.

About 10.40 and again at 11.15 p.m. the St. Petersburg needle is deflected to the west, and the Kew needle toward the east. The St. Petersburg needle reaches its maximum at 11.30 p.m., then both needles move eastward until 12.10 a.m., after which the Kew needle begins to move westward. At 12.30 a.m. the St. Petersburg needle also begins to move westward, the curves very closely agree, and the disturbance is very nearly over.

On July 19, before seeing the Kew horizontal force curves, I wrote as follows: *I am led to conjecture that at* 8.45 *p.m. on the* 29*th, and at* 11.15 *p.m., there is an increase in the horizontal force.*

On comparing the Kew horizontal force curves I find that from 8.45 to 9.5 p.m. the horizontal force is increasing rapidly, and that it decreases again from 9.5 to 9.30 p.m. At 10.40 the horizontal force again increases, and after a slight decrease about 11 o'clock, there is again an increase in the horizontal force, beginning at 11.15 p.m., and ending at 11.30 p.m., *i.e.*, when the St. Petersburg declination needle reaches its greatest westerly deviation.

On comparing an exceedingly good photograph from Vienna for March 26–27, with the photograph from Kew, which is also good, in a disturbance lasting from 5 p.m. to 7 p.m., in which there were twelve distinct deflections in each direction and a decided character given to the curve, but in which no excursion was as great as 2′ from the mean position, I found that the curves were absolutely coincident.

The Stonyhurst positives agreed with Kew as far as one could judge, but the agreements between the Kew and Vienna curves here spoken of are such as are entirely beyond the power of testing by a positive. Almost the whole of the Vienna photograph of the disturbance lies within the breadth of the base line in the Stonyhurst positive. The oscillations are also found to take place absolutely at the same instant of time at Kew and at Vienna. Similar instances occur on March 31 between 12 and 1 p.m. and between 6 and 7 p.m.

The St. Petersburg tracings also show the same disturbances occurring at the same times, but the agreement of these Vienna and Kew curves is far greater than any that can be tested by means of tracings; at the same time, there are numberless instances of comparison which might be given which show that the St. Petersburg tracings are remarkably good. They are also taken on a very excellent tracing paper, and the hours are carefully marked on the curves, so that there is no difficulty in arriving at the time at which any given disturbance occurs.

It would be easier to make accurate measurements of time if the base line were nearer to the curve than it is in the Vienna photographs, and if only one curve were photographed on each slip at all stations, as is the case in the Vienna photographs. For the comparison of magnetic disturbances it is important that the arrangement of lamps, lenses, &c., should be as exactly as possible the same at all stations, for the accuracy of the agreement of the results is such that any variation in this arrangement interferes with the degree of accuracy of the conclusions which may be drawn as to the character or the cause of magnetic disturbances.

First Report of the Committee, consisting of Professor A. LEITH ADAMS, the Rev. Professor HAUGHTON, Professor W. BOYD DAWKINS, *and* Dr. JOHN EVANS, *appointed for the purpose of exploring the Caves of the South of Ireland.*

THE following is a preliminary Report on the Bone Caverns, near Middleton, in the county of Cork, lately explored, in part, by R. J. Ussher and J. J. Smyth, Esqrs. The work has been restricted to a few days'

diggings in the superficial deposits. These, however, are sufficiently encouraging, and will be renewed on the first favourable opportunity.

A. LEITH ADAMS,

July 21, 1880. Secretary of the Committee.

Report on the Caves and Kitchen-midden at Carrigagower, Co. Cork. *By* R. J. USSHER.

These caves, whose original mouths are now probably destroyed or concealed by rubbish, open at present into a quarry in a limestone knoll on the townland of Carrigagower ('Rock of the Goat'), three or four miles south of Middleton. They are not broad nor lofty, but have extensive ramifications, especially that one which opens into the north-west part of the quarry. At its eastern end, and at a depth of 20 feet from the surface, the quarry is crossed by a cave now exposed by the removal of its western side. This cave runs in the line of a joint or fissure, and penetrates the rock north and south. The floor of this cave, where it remains (through the northern half of the exposed portion), is of stalagmite resting on pale sandy clay that overlies the limestone bottom. On this stalagmite floor, among the *débris* of broken stalactites, loose charcoal was found, and, on removing a layer of the solid stalagmite, from 1 inch to 2 inches in thickness, much charcoal was found embedded in it, with sandstone gravel and some shells of a small *Helix*, marking the horizon of an old floor that had been encrusted by the subsequent formation of stalagmite. The portion of the cave laid open appeared in its southern part to have had no stalagmite floor, but to have had an upward opening to the sky, through which an accumulation of brown surface-earth and kitchen waste had been introduced, extending downwards into the cave so as to have completely filled this vertical opening. The accumulation was uniform in character, containing much charcoal, often in large lumps, and a great profusion of bones and teeth of ox, sheep or goat, and pig, with some remains of horse, dog, and cat, and a few of hare and rabbit. The bones were usually broken. Their colour was generally yellowish, but often blackened, though they exhibited no appearance of dendritis. In some instances they appeared to have been burned, and charcoal was very frequently found adhering to them and in their interstices. Numbers of sea-shells occurred through the accumulation. Seven species of these were noted, the most common being limpet and periwinkle. Many shells of the common garden-snail also occurred. With the above were found several articles of human use. Sharpening-stones of different sizes, flat circular pebbles, hammer-stones, flint-flakes artificially chipped, a fragment of wheel-made pottery, two iron knives of an antique form, an iron chisel, and a large flat-headed iron nail, some slag and a piece of jet (?). A portion of a jet bracelet had previously been found in the same brown surface-earth close to this spot. J. J. Smyth, Esq., to whose kind assistance we are much indebted, found in a recess, close to the above spot, a portion of the upper stone of a quern embedded in earth. Near the centre of the quarry, a portion of a cave remains that has been partly quarried away. In this was discovered, with bones of deer and ox, part of another stone, very similar to the above portion of a quern, with a flat surface and a circular hole in it, though not in a direction exactly perpendicular to the surface. In the surface of an adjoining field a deeply indented arrowhead of flint was found some time since, and labourers

employed on the spot say that triangular chipped flints have frequently been met with there. The surface-earth around the quarry contains many bones of ox, goat, and pig, showing that the spot had been the site of some human habitation for a considerable lapse of time.

Further explorations in this cavern have been postponed, but will be resumed presently.

Extract from a Report by ROBERT DAY, Esq., *F.S.A., on the Implements found at Carrigagower, Co. Cork.*

The iron objects are peculiarly interesting, as examples of very early domestic articles—comprising a chisel and two knives. The larger of these has a portion of the wooden haft still adhering to it, and the turn-up on the handle part, designed for securing it effectually, occurs on a larger knife in my collection which was found at Larne, Co. Antrim. These objects lack the peculiar blue or cobalt patina that is so frequently found on iron tools from Irish crannogs. The oblong stone with polished sides is a burnisher or whetstone, upon which probably the knives were once sharpened. The broken stone may either have been a hone stone or a chisel-shaped celt. If it was found in the same deposit as the iron objects, I should say it was another polisher, as it is not probable that a chisel of the advanced iron type would be found in conjunction with one of stone. Two of the natural pebbles are hammer-stones, and the third, with its ground and partly polished face, is one of a type commonly met with in the North of Ireland. In this the central depression is barely defined, but in others it is much more fully developed, so that I have long come to the conclusion that, while serving some purpose (perhaps for grinding the broken points of arrowheads), they were made to pay a double debt, and served as amulets! I noticed upon the broken bit of pottery what looks very like a worn-out inscription in Roman capital letters. This is best seen with a pocket lens. The bit of jet (?) may be jet or coal; I am not competent to give an opinion. The fragments of flint are all artificial. Among them is the base (showing the bulb of percussion) of a worked flake. These flint-flakes were used down into the iron age, and we have here another proof of the fact. The bone scoop sent by Mr. Smyth is, from the character of the texture or structure of the bone, altered by exposure and time, as it is unquestionably older than the apple-scoops which schoolboys made in the present century, and which it closely resembles. I have another like it, from the Lough Revel Crannog, Co. Antrim, with cobalt patina. This from Rathcoursey (Carrigagower) is ornamented, and the flint arrowhead found there is small, beautifully chipped, and of the scarce and deeply indented type.

The iron nail is very curious, with a head like a horse nail.

Report of the Committee, consisting of Mr. SCLATER, Dr. G. HARTLAUB, Sir JOSEPH HOOKER, Captain F. M. HUNTER, *and* Lieut.-Col. H. H. GODWIN-AUSTEN, *appointed to take steps for the Investigation of the Natural History of Socotra.*

COLONEL Godwin-Austen having been unable to carry out his intention of going to Socotra, the Committee were fortunate enough to obtain the services of Dr. I. B. Balfour, Professor of Botany in the University of Glasgow, for this purpose. Prof. Balfour left this country on January 9, for Aden, and returned home on April 21. As his report of proceedings, &c. (appended), will show, he has, considering the short time (only six weeks) that could be devoted to the investigation of the island, and the inevitable delays and difficulties always attending the first exploration of an unknown country, not only achieved a remarkable amount of success, but has proved how much more rich the island is than was anticipated, and how much is left for future explorers.

The total expenditure of Prof. Balfour on his expedition amounted to about 420*l.* The Committee having received 100*l.* from this Association, and 300*l.* from the Government Grant Fund of the Royal Society, there remains a debt of about 20*l.* due to Prof. Balfour.

The Committee request that a grant of 50*l.* may be made to them to enable them to discharge this debt. The balance they propose to devote in aid of the publication of the results obtained by the expedition.

The Committee consider that the best thanks of the Association are due to Prof. Balfour for having undertaken this expedition, and for the zeal and industry with which he has carried it through.

The Committee consider that the best thanks of the Association are also due to Brigadier-General Loch, C.B., Resident at Aden, Major Goodfellow, Assistant Political Agent, and Captain Heron, of H.M.S. *Seagull*, for the great assistance they have rendered to Prof. Balfour on this occasion. The success of the expedition is, as Prof. Balfour informs us, mainly due to the cordial co-operation of these gentlemen.

Referring to the report of Prof. Balfour, the Committee feel no doubt that in every branch of science considerable results are yet to be obtained by further investigations in Socotra, and are of opinion that a second expedition should be sent out as soon as the necessary facilities can be obtained.

Report to the Socotra Committee of the British Association for the Advancement of Science of the proceedings of the Expedition to the Island of Socotra. By BAYLEY BALFOUR, *Sc.D., M.B., Regius Professor of Botany, University of Glasgow, in charge of the Expedition.*

Having undertaken at the request of the Committee the work of an expedition to the Island of Socotra, for the purpose of investigating its Natural History, I left England on January 9, and joining the French mail steamer *Ava* at Marseilles, reached Aden on the 24th of that month. I was accompanied by Alexander Scott, a gardener from the Royal Botanic Garden, Edinburgh.

On arrival at Aden, I met my friend Dr. Hay, the Port Surgeon, to

whose kindness I am much indebted, and with his aid I was enabled to make a fair collection of the plants of Aden. Captain F. M. Hunter, Junior Assistant Political Resident, a member of your Committee, was not at Aden at this time, having gone to the interior a few days previously, and as he had no prospect of returning to Aden before the expedition left for Socotra, he had left for me a letter of instruction, giving valuable information and hints, the outcome of his personal experiences on the island. In his absence Major Goodfellow, Senior Assistant Political Resident, gave me every assistance, and the attainment of the object of the expedition is in great part due to him.

The official letters of recommendation to the authorities at Aden from the Home Government, for which the Committee applied, had not reached Aden at the date of our arrival, but having a private letter of introduction from General Strachey to Brigadier-General Loch, C.B., Political Resident, I presented it. General Loch very cordially sympathised with the object of the expedition, and promoted most materially the carrying out of the work of the expedition. In default of instructions from the Home Government he telegraphed to the Bombay Council asking for authority to aid the expedition, and received a very gratifying affirmative reply. He then at once placed the despatch boat *Dagmar*, of the Bombay Marine, at our disposal to convey us to Socotra, and we were enabled to obtain from the arsenal, tents and camp implements. He also very kindly granted leave to Lieutenant Cockburn, 6th Royal Regiment, that he might go with us to Socotra. Lieutenant Cockburn then joined the expedition, and apart from the advantage and pleasure I derived from having him as a companion, the excellent sketches [1] he made will enable the Committee to judge of how great an acquisition he was to the staff of the expedition and of the valuable services he rendered.

The P. & O. mail steamer arriving on January 26, brought the promised official letters, one from the India Office to the Resident, and another from the Admiralty to the Senior Naval Officer at Aden. As a result of the latter letter, Captain Heron, of H.M.S. *Seagull*, called upon me on the 27th and offered to take the expedition to Socotra in his ship. It was subsequently arranged, therefore, that we should go in the *Seagull* instead of the *Dagmar*, and the date of sailing was fixed for February 2.

The intervening days were occupied in obtaining stores and servants; the latter not easy to procure, especially a good interpreter, on account of the very high rate of pay demanded.

All our gear was shipped on the *Seagull* by noon on February 2, and our party—composed of Europeans,—Lieutenant Cockburn, Alexander Scott, and myself; and natives,—interpreter, cook, tent Lascar, general servant, and two coolies—went on board later. Captain Heron purposed to sail that day, but the monsoon blowing strongly up the harbour a start was delayed until next morning. On the morning of the 3rd, though the wind had not much lulled, anchor was weighed and the *Seagull* steamed out of Aden harbour in the teeth of a stiff breeze. By the afternoon we had made so little way against the wind and current, and were pitching and rolling so greatly, that Captain Heron determined to put back and make for Aden again. The expedition at the outset thus encountered annoying delay, for we remained in Aden Harbour until the morning of February 6, when again the *Seagull* left for Socotra. Heavy

[1] Some of the sketches were exhibited at the meeting.

weather kept us back, on this our second attempt, and it was not until the morning of the 11th that we sighted Socotra.

I desired to land at Hadibu, the chief village of the island, where the Sultan has his Court; but as much coal had been expended on the voyage, and the anchorage at Hadibu being reported unsafe, Captain Heron deemed it advisable to anchor in Gollonsir Bay, a bay considered the safest round the island, and at its north-west end.

From the village sheikh we learned that the Sultan was living at his hill residence, some miles from Hadibu. We therefore sent by messengers the letter of recommendation furnished to us by the Aden Government. But it was not until February 16 that an answer arrived at Gollonsir—an answer of a very satisfactory kind, allowing us to go where we pleased, and charging the village sheikh and the people of the neighbourhood to aid us if possible. Whilst waiting for news from the Sultan, our tents, stores, and baggage were landed from the *Seagull*, and our first camp was formed on the slope of a hill N.E. of the Gollonsir village, and we entered on our work.

The *Seagull* left on February 16.

Making in the first instance Gollonsir our head-quarters, we explored the adjacent country to the S. and S.W., until the 25th inst., when we struck tents, and sending our heavy baggage and stores by sea, started to march to Hadibu. We took four days to accomplish it, reaching Hadibu late on the night of the 28th inst.

Having communicated to the Sultan the fact of our arrival, he came to Hadibu on March 1, when we had an interview.

Establishing our depôt now on the Hadibu plain, about a mile from the town, we spent the time until the 7th inst. investigating the magnificent Haggier range of hills shutting in on the south the Hadibu plain.

On March 8, leaving a tent Lascar in charge of the depôt at Hadibu, we started upon a trip to the eastern end of the island, going eastward along the northern side and returning westward by the southern side of the island. During this trip we reached Ras Momé, the extreme eastern headland. Camp at Hadibu was again entered on March 18.

As yet we had not seen much of the southern parts of the island, so on March 22 we left Hadibu on our last excursion. Crossing the Haggier range we emerged upon the southern shore at Nogad, traversed the coast line for some distance, and then recrossed the island, so as to come down upon Kadhab village on the north side. We regained Hadibu on the 27th.

March 28. The *Dagmar* arrived this morning, having been sent specially for us by the Resident. We were not sorry to see her, as our camp was now very sickly—Scott was down with fever, one coolie had had sunstroke, and the other servants were all suffering badly from fever. So much so that for some time previously hardly one of them could work, and we had been compelled to hire some of the Sultan's men.

Having shipped our collections and gone on board the *Dagmar*, she left Socotra on March 30, and after a smooth but tediously slow passage reached Aden on April 3.

Here on our return we experienced as much kindness as before. General and Mrs. Loch extended to me their hospitality at the Residency. Our collections were overhauled and finally packed for transmission to Britain by the P. & O. steamer *Deccan*, which reached Aden early on April 10. By this steamer I also took passage, and travelling to Brindisi,

arrived in London on the 21st. Alexander Scott went by the *Deccan* to Southampton, which brought him to England with the collections early in May. Lieutenant Cockburn rejoined his regiment at Aden.

Collections of specimens in all branches of Natural History were made. As may be supposed I devoted particular attention to the Botany of the island, and there are dried specimens of between 500 and 600 species of flowering plants in the collection, besides some Cryptogams. A certain number of specimens were brought to England alive, amongst them being such interesting plants as the Dragon's-blood tree and the true Aloe. A misfortune deprived me of a number of living plants, and on this wise:—Having selected the majority of the more delicate living plants I purposed to bring them with me to London, as thereby they would arrive a fortnight earlier than by going by Southampton. At Brindisi, however, the Custom House officer seized the plants and insisted on their being taken back to the ship, not allowing me even to book them by another steamer which would have taken them more directly to England. Consequently the plants had to travel up to Venice and thence back to Suez before they could be forwarded to Britain. And all this because the Italian Government dreads the introduction of the Phylloxera into Italy, forgetful apparently of the fact that it is already abundant in the country, and also that it lives only on vines.

Specimens of the gums produced on the island and used in commerce have been brought home. In the zoological collections there are a few snakes and lizards, some birds, freshwater fish, Mollusca, Crustacea, and Insecta of various kinds.

Some of the land Mollusca have come to this country alive. Two living civet cats I was bringing for the Zoological Gardens died on the way home.

Illustrative of the geology of the island are about 500 specimens of rocks and minerals from various localities on the island. Igneous, metamorphic, and sedimentary rocks are all represented.

I regret that I was unable for some time after my return to turn my attention to the distribution of the collections for examination. I have recently, however, done so, and the following gentlemen have kindly consented to examine certain groups:—

Zoological.	Birds	Mr. Sclater and Dr. Hartlaub.
	Land shells . . .	Col. Godwin-Austen.
	Crustacea . . .	Prof. Huxley.
	Remaining Zoological collections . . .	Dr. Günther and Zoological staff of British Museum.
Geological.	Igneous and metamorphic rocks . . .	Professor Bonney.
	Sedimentary . . .	* * *
Botanical.	Algæ . . .	Dr. Dickie.
	Fungi . . .	Dr. M. C. Cooke.
	Mosses and allies . .	* * *
	Flowering and vascular Cryptogamic plants . .	Dr. Bayley Balfour.

The agreement made with the Committee as to the final disposition of the specimens will be carried out, viz., the first set of specimens, zoological, to go to the British Museum; the first set of specimens, botanical, to go to the collection at Kew; a set of botanical to go to the British

Museum. The remainder will be distributed variously. The publication of results is a matter for consideration by the Committee.

In the foregoing report I have confined myself to a narrative of the proceedings of the expedition. It is as yet too early to speak definitely of what the total results will be. But I think I may safely say, from what I have learnt regarding the birds from Mr. Sclater, and regarding the land shells from Col. Godwin-Austen, as well as from what I know of the plant collections, that the results promise to be of exceptional interest. What has been done by the expedition is but a fragment of what there is to be accomplished. In exploring the island, I deemed it better, considering the short time of our sojourn, rather to attempt to cover as much ground as possible, with the view of obtaining a representative collection, than to examine in detail a limited tract of country. By doing this, much barren land was travelled over, and many rich and fertile spots were necessarily only superficially looked at. Especially amongst the hills of the Haggier range are there valleys which would well repay a careful and extended investigation. The expedition just completed ought to be considered only preliminary, for I am assured a rich harvest awaits any collector who may visit the island.

If at any future time an expedition should be sent to the island, it would be well if the date of its arrival were timed so that it should have the last months and the first months of a year upon the island. Our expedition reached the island too late in the year, so that before we left the heat was so intense as to prevent our doing so much work as we desired. Again, the inaccuracy of our knowledge of the geography of the island is a point to which the attention of future expeditions should be directed. The chart based on Wellsted's observations is the only available one, and that is so incomplete and incorrect as to be almost useless to anyone moving about the island.

In conclusion, I desire to express my hearty thanks, and those of the other members of the expedition, to the Committee for their aid. Also to General Loch, C.B.; Major Goodfellow; Dr. Hay; Capt. Heron, R.N., and officers of H.M.S. *Seagull*, and to the officers of the despatch-boat *Dagmar*, for the very kind way they one and all co-operated to make the expedition successful.

Report of the Committee consisting of the Right Hon. A. J. MUNDELLA, *M.P.*, JAMES HEYWOOD, Esq., *F.R.S.*, STEPHEN BOURNE, Esq., CHAS. DONCASTER, Esq., the Rev. A. BOURNE, TAISO MASAKI, Esq., CONSTANTINE MOLLOY, Esq., R. J. PYE-SMITH, Esq., Dr. HANCOCK, *and* ROBERT WILKINSON, Esq. (*Secretary*), *appointed to consider and report on the German and other systems of teaching the Deaf to speak.*

THE Committee was appointed to consider this subject in consequence of the reading of a paper at Sheffield by Dr. David Buxton.

The General Committee, by this appointment, confirmed the resolution of the Sectional Committee, and of Dr. Buxton's audience—'That a Training College for Teachers of the German system of teaching the deaf—by speech and lip reading—is a matter of national importance,' and

it was referred to this Committee to consider the best means of promoting the adoption of this system throughout the country.

In pursuance of this reference, they have made themselves acquainted with the most recent publications upon the subject, consultation has been held with, and valuable information received from, persons of eminence and known experience in this department of education, and lengthened visits have been paid to each of the schools, in and near London, where deaf children are taught upon this system.

In the paper read at Sheffield, it was pointed out that other countries performed their work of this kind better than it had hitherto been done in this country:—

1. Because they employ the 'German' system in preference to the 'French' or 'Combined' method, their pupils being taught by 'Speech,' and not by 'Signs.'
2. Because they employ a superior class and a larger number of Teachers, who, where it is possible, are specially trained for the work, not promiscuously engaged in it, as with us.

To which may, we think, be added further:—

3. Because this department of Education is undertaken and supervised by the State in other countries; not left, as here, to the direction of bodies of men whose chief qualifications for the office are their annual subscription and their kind-heartedness.

More, probably, than any other person engaged in education, the teacher of the deaf needs the encouragement which springs from an intelligent sympathy. The entire field of education is a vast one. The instruction of children who are deaf is but a very limited portion of that field, into which very few persons thoroughly enter. To those who labour in it, and those who are brought into connection therewith by family ties, the close study of this subject has been almost exclusively confined. We may add, also, in passing, that the repelling character of the sign system is greatly to blame for this. And it has come to pass that those who have supported the schools and asylums for the 'Deaf and Dumb' have done so, not from any special knowledge or sympathy, but on the general grounds of philanthropy, charity, or religion; and those who have administered their affairs have done so in utter ignorance of the peculiar condition and necessities of the class over whom they were the, generally, self-constituted guardians. The first feeling of surprise that the born-deaf could be taught at all has sufficed to keep these kindly unintelligent observers satisfied that *something* was being done. How inadequate that 'something' really was—how far below both the necessities and the possibilities of the case, they knew not, nor cared to know. In recent years, however, a change has taken place. The attention attracted to the subject, by papers which have been read, and discussions which have followed, in our own and kindred societies, the reported observations of travellers abroad, and articles in the daily and periodical press, have all gained for it a large amount of interest among men of science, medical men, the clergy, and the educated classes generally; and probably the very first wish of all persons who have to deal with the future of any deaf child has now come to be the wish to have it educated on the 'German' system. This advantage has, however, been all but unattainable, since nearly all the public asylums and schools in the country are conducted on the 'French' system. To discover and point out the advantages of a

better method, and to make those advantages easier of attainment, are, we believe, the objects we were appointed to promote, and to this purpose thus understood we have assiduously applied ourselves in our present enquiry.

That a large proportion of the deaf children of this country are growing up without education, we think is undeniable. The blessing of education to the individual, and the burden to the community of an uneducated deaf and dumb population, impart to this question an importance which cannot be gainsaid. Whenever it is the foolish—and in this case culpable—reluctance to part with the child which keeps it at home in lifelong ignorance, we think compulsion is necessary. Thus far as to children *not* at school: our verdict is that they ought to be sent there, and that it is the nation's duty to send them. Of those who *are* at school the nation should further see that the best is made of the opportunity (1) by those who go to learn, and (2) by those who claim to teach.

1. To those who learn, sufficient time should be given. They should not be kept waiting for admission on the chances of election by the votes of the subscribers; nor should they be prematurely taken from school through failure of funds for paying the fees, or the eagerness of parents to get them employed.
2. Those who teach should be furnished with the best advantages in the way of training, remuneration, and status; and they should instruct the pupils committed to their charge by the best methods which are attainable.

That the 'German' system — speech and lip-reading — is the best method of instruction for the deaf, we entertain no doubt whatever. No other system can be placed in comparison with it. That it should not be applicable in this country to English children, when it is found in successful use in Germany, Holland, Italy, and other countries, is a plea which cannot be seriously entertained. What is not good enough for those countries cannot be admitted to be good enough for us. This was forcibly put before the Section at Sheffield last year, and we heartily endorse it. To the Training College for teachers, now established at Ealing, we look for results of the greatest importance. A course of systematic and professional training, and a system of granting certificates after examination, form an entirely new departure in the education of the deaf. Nowhere was such a change more needed. Improvements in every other department of educational work left this sole exception only the more observable.

If the new movement is well supported and fully developed, the great hindrance to future progress will be removed. That hindrance we find was this—The persons engaged as teachers had no qualifications for their work, and they were first required to learn the sign-language of the pupils—to descend to the pupil's level. The newer system is, to instruct the pupil in the language of the teacher, and so to raise him to the teacher's level. A generation of practice on this principle will work a change not easy to realise. It will assimilate the deaf, as far as possible, to the intellectual and social condition of those who hear, and will break down those restraints which confine them amongst themselves, and make them more and more 'deaf and dumb,' thus confirming and strengthening that introversion of character which is natural, and which wiser methods and wider influences would unfold and develop, to their far greater happiness.

In order to promote the valuable objects we have described we recommend—

1. That Parliamentary Grants be made for the Education of the Deaf on the 'German' system.
2. That the Grants be made to meet all the educational needs of any given district or locality, and that a sum in proportion to the number of deaf pupils therein be appropriated for their benefit.
3. Aid to Training Colleges, or Grants to approved Students desiring to be trained.

Report of the Committee, consisting of Mr. JAMES HEYWOOD, Mr. SHAEN, Mr. STEPHEN BOURNE, Mr. WILKINSON, the Rev. W. DELANY, *and* Dr. J. H. GLADSTONE (*Secretary*), *appointed for the purpose of reporting whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the scientific specific subjects of the Code in addition to other matters.*

THE Committee nominated at Sheffield for the purpose of considering 'whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the scientific specific subjects of the Code in addition to other matters,' have received a considerable amount of evidence upon the subject, and beg to report as follows :—

1. It has come to their knowledge that the teaching of the scientific specific subjects is practically discouraged by the incapacity of many of H.M. Inspectors to examine in them.

2. This incapacity is explained by the fact that the Inspectors are not generally chosen so much for their fitness to judge of such educational work, as on account of their high scholarship, or through political patronage.

3. In the opinion of this Committee there might be an examining body for H.M. Inspectors, composed of three of the most experienced of the present senior Inspectors, associated with a similar number of the Science Examiners of the Science and Art Department. The examination should be thrown open to Elementary Teachers, and the candidates might be tested in the practical work of examination in one of the Central Elementary Schools in London.

4. The Committee believe that the opening of the Inspectorship to fully qualified Elementary Teachers would tend to raise the *esprit de corps* of the profession, and improve the character of both Inspector and Teacher.

5. The Committee are further of opinion that while a university degree may be fitly regarded as a test of scholarship, it is not a test of the particular qualifications for an examiner, and therefore is not sufficient in itself to guarantee the holder thereof as worthy the position of Inspector. There appears to be no reason why academical honours should be made an indispensable condition of appointment.

6. The Committee recommend that a Memorial be presented to the Lords of the Committee of Privy Council on Education embodying the above conclusions.

On the Anthracite Coal and Coal-field of South Wales. *By* C. H. PERKINS.

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

THE anthracite or 'stone coal' deposit of the British Islands is confined, with slight exception, to a small portion of the South Wales coal-field. But, limited as it is, it possesses features of an unusually interesting and attractive nature, both in respect to its geological character and the peculiar quality of the coal itself. In considering this subject it will be desirable to bear in mind some of the leading features of the coal-field alluded to, of which, as stated, the anthracite deposit forms a part.

The South Wales coal-field has its eastern boundary near the centre of Monmouthshire, and extends from at or near Pontypool in that county, in a westerly direction, until lost in the waves of the Atlantic Ocean, or, more correctly speaking, the Irish Channel, in St. Bride's Bay in Pembrokeshire. It thus traverses a distance of over 90 miles. To this considerable length its breadth forms a proportion by no means commensurate, as it nowhere exceeds 21 miles. We are now standing within two or three miles of the southern outcrop of the coal basin, and a crow's flight northwards of 15 or 16 miles will bring us to the north outcrop in Carmarthenshire. The sides and bottom of this great geological valley are composed of mountain limestone, within which are piled up the various carboniferous strata to a maximum depth in the centre of over 3000 yards.

This valley or basin is marked by two distinct troughs. The south, the smaller one of the two, extends from the Sirhowy valley on the east to the neighbourhood of Aberavon on the west; while the larger or north trough reaches from Llanelly through Morriston, Neath, and Blackwood, to Pontypool on the east. The south trough passes out of the coal measures near Swansea, leaving to the west but one basin, a continuation, in fact, of the north trough, with which, in respect to anthracite, we have alone to do. From the centre of this basin, where the measures lie flat or nearly so, the rise may be regarded for our present purpose as north and south, though in reality nature has not followed minutely these cardinal points. 'Level course' would thus run in the main east and west, and, as a rule, the faults cut it in a transverse direction. These faults are frequently of great magnitude, showing at times a displacement up to 200 to 300 yards.

The quality of the South Wales coal ranges from the pure anthracite or 'stone coal' to the semi-anthracite or Welsh steam coal, and onwards to the highly bituminous or smith's and gas coal. There is also a considerable quantity of coal commonly known as 'bastard anthracite,' the quality of which is extremely inferior; for while debarred of the purity and strength of anthracite, it does not possess the opening or swelling faculty of the steam coal, and decrepitates when burning to an unusual degree. Anthracite or 'stone coal,' with the exception of the Pembrokeshire portion of the coal-field, is found exclusively on the north rise. I use the term 'stone coal' advisedly, for that of anthracite has, with more or less correctness, been applied to coals which, while bearing an affinity to it, are yet far removed from this, the diamond of the British coal-field,

so beautiful in appearance, so pure and powerful in combustion, and so cleanly in its nature. The deposit may be said to commence on the east, at the higher points of the Neath valley. At Kidwelly, on the west, it is submerged under the waters of Carmarthen Bay, again to reappear at Saundersfoot in Pembrokeshire, and finally to be lost in St. Bride's Bay. Its limitation to the north rise renders the width of the deposit extremely narrow, the more so as stone coal jealously refuses to mingle with its less carboniferous kindred, and a barrier of intermediate quality intervenes as a rule between it and the bituminous seams of the south rise; but to the north the mountain limestone and its associated strata alone check the operations of the stone coal worker. The gradual transition in their quality, which the same scenes present, renders a definition of the anthracite boundaries extremely difficult. Speaking roughly, I estimate the length of the deposit, exclusive of Pembrokeshire, at 30 miles, with an average breadth of 6 miles. Upon this supposition we should have an area of 180 square miles or 115,200 acres. In addition to this the portion beneath the sea in Carmarthen Bay is 15 miles in length by 6 in breadth; and the Pembrokeshire coal-field extends for 20 miles, with an average width of 5 miles. I have not considered it necessary within the limits of this paper to enter into any minute calculation regarding the quantity of workable coal now existing in the leading portion of the deposit. I allude to that lying eastwards of Carmarthen Bay; but I believe we shall be within the mark in estimating an average thickness to exist of 35 feet of workable coal, affording a yield of some 35,000 tons to the acre. An allowance must, of course, be made for the workings that have already occurred; but they can have made but an insignificant inroad into the enormous mass of magnificent fuel which here lies for the benefit of mankind and the exercise of science and art, in the provision of the best means for its utilisation. The coal-field may be divided thus:—

1st. The Pembrokeshire district.
2nd. The Gwendraeth Valley district.
3rd. From thence eastwards to the Vale of Neath in Glamorganshire.

I have already stated the area of the first, which, according to the report made to the Royal Coal Commission, contains over two hundred and fifteen millions of tons of workable coal, all anthracite. The ground is here much disturbed, and the seams, as a rule, thin; but the quality of the coal, more especially the 'Kilgetty' and 'Timber' veins, is probably the finest in the world. Mr. Thomas Foster Brown, in his interesting paper upon the South Wales coal-field, gives a list of seven workable seams, containing an aggregate thickness of 17 feet 9 inches, and lying within a depth of 980 feet.

The Gwendraeth Valley, in Carmarthenshire, is rich in both coal and iron ore. At its upper end the quality is highly anthracitic, modified to some extent as we approach the sea at Barry Port or Pembrey. There are some twenty-two seams of coal, varying from one to nine feet in thickness, that crop out in this valley, with a collective thickness of over 60 feet. I am quite unable, within the limits of this paper, to enter into any detail of the mineral features of this and the adjoining district, reaching, as before stated, to the Vale of Neath. I must confine myself to simply pointing out the abundance of its resources. The seams of coal are numerous, and range even up to 18 feet in thickness, all producing anthracite, but, as usual, varying to some extent in quality. The

'Big Vein' of the Aman Valley, known as the 'Stanllyd' of the Gwendraeth and Mynydd Maur districts, has the highest reputation for purity and strength. This seam must not be confounded with the 'Nine-foot' vein, to which the appellation of 'Big Vein' is sometimes applied, both in the Gwendraeth Valley and at Mynydd Maur.

Another well-known seam is the 'Brass' vein, known also as the 'Peacock' and the 'Diamond' vein, which attains its best condition in the Swansea Valley, and is greatly esteemed for the various purposes to which anthracite is applied. Many of the other seams are also deserving of special notice; but having given such a description of the coal-field as may lead us, to some extent, to realise its value in respect to its resources and productive power, it will be desirable to consider the difference, chemical and otherwise, that distinguishes pure anthracite from semi-anthracite and bituminous coals; and here we are necessarily met with the same difficulty as in attempting to define the boundaries of the coal basin, and from the same cause, that of the gradual and almost imperceptible merging into each other of the coals referred to. Professor Dawkins says: 'The whole difference between anthracite coal and ordinary coal consists in this, that the bituminous portion of the anthracite has been removed in some way; while in the case of ordinary coal, the hydrogen and oxygen of the bituminous part still remains.' But this definition still leaves us to determine where anthracite ends and bituminous begins; and, in considering this portion of my subject, I have felt myself compelled to fall back upon the analysis I have before me of a few of the coals worked in the South Wales basin, which are recognised as examples of the various descriptions referred to.

PURE ANTHRACITE.

PEMBROKESHIRE.

	'Lower Level Vein.'	'Kilgetty Vein.'
Carbon	94·18	93·27
Hydrogen	2·99	2·72
Oxygen	·76	2·47
Sulphur	·59	·15
Nitrogen	·50	·18
Ash	·98	1·21
	100·00	100·00

CARMARTHENSHIRE.—*Aman Valley.*

'Big Vein.'

Moisture	0·107
Carbon	92·558
Hydrogen	2·109
Oxygen and Nitrogen	4·678
Sulphur	·120
Ash	·428
	100·000

Swansea Valley.

'Brass Vein.'

Carbon	91·11
Hydrogen	3·55
Oxygen and Nitrogen	3·24
Sulphur	·59
Ash	1·51
	100·00

Passing from these several examples of pure anthracite, I have selected a coal worked at Ynismedu, in the Swansea valley, and thought to be the same vein as the 'Four-foot' of Aberdare, as a type of the 'bastard' anthracite of the district, the analysis of which is as under:—

Carbon	89·18
Hydrogen	4·04
Oxygen and Nitrogen	3·44
Sulphur	0·71
Ash	2·63
	100·00

As an example of the celebrated South Wales steam coal, I shall not be wrong in giving the analysis of 'Nixon's Merthyr' as follows:—

Carbon	90·27
Oxygen	2·53
Nitrogen	·63
Hydrogen	4·12
Sulphur	1·20
Ash	1·25
	100·00

That of the 'No. 3 Rhondda' vein I quote from 'Fairley's South Wales Coal-field,' as one of the best known and most valued bituminous seams of the district, the analysis of which is as under:—

Carbon	72·73
Oxygen and Nitrogen	22·60
Sulphur	1·17
Ash	3·50
	100·00

From these details it will appear that in the chief constituent, carbon, the purest anthracite exceeds the 'bastard' anthracite by 5 per cent., the best Welsh steam coal by 3·91, and the bituminous coal by 21·45 per cent. But, on the whole, and regarded simply in a practical light, I consider these returns singularly unsatisfactory; I may almost add, deceptive. I allude particularly to the analysis of the 'bastard anthracite' and that of the Welsh steam coal. In the examples I have given there is but a difference of 1·9 in carbon, ·8 of hydrogen, and ·28 in oxygen and nitrogen. And yet practically, and for all marketable purposes, no greater divergence can exist.

I must leave it to the chemist or others to explain this difficulty, one which also to some extent exists in respect to the Welsh and American anthracites. Judging from analysis, appearance, and general characteristics, these fuels are connected by the closest ties; and yet, while our Welsh coal, with all its splendid attributes, is neglected and, excepting for a few purposes, shunned and despised, its great American brother enters into wide and general use. Much of this is due, no doubt, to habit, custom, and necessity; and I also believe that the rendering of the coal for market in pieces of various and suitable size, as adopted in America, is a very great convenience, and would, if followed in this country, greatly increase the trade of the anthracite worker. We should, however, look deeper into the matter for a solution of the problem. Dr. Percy indeed says with respect to anthracite coal, 'The property of decrepitating may cause the production of fine particles to such an extent

as seriously to check the passage of air through a furnace in which anthracite is used for fuel, even when the air is impelled by a blast engine. It is a property belonging to Welsh anthracite, and to some varieties of it to an extraordinary degree, but not, I am informed, to the anthracite of the United States of America.' However this may be, we know that anthracite does not possess the opening or swelling qualities of the Welsh steam coal, nor the binding or caking properties of the bituminous coal. And thus we have occasion for the introduction of appliances for securing perfect and more rapid combustion; to which, in alluding to the history of anthracite, in respect of the various purposes to which it is applied, or sought to be applied, I shall venture to direct your attention.

This history is replete with the records of attempts made to extend the use of this fuel. Imbued with the knowledge of its inherent strength, its purity and admitted advantages, persons have come forward through a series of years—some actuated by personal interest, combined with a desire to promote the public good, others through the latter incentive alone, and have spent money, time, thought, and labour upon this object, but unfortunately with but little success.

To this day, the use of anthracite in this country is practically confined to malting, hop-drying, and lime-burning, and consequently the resources of this fine coal-field remain practically undeveloped.

As early as the year 1595 attention seems to have been drawn to the valuable qualities of anthracite coal. Writing in that year a history of Pembrokeshire, George Owen, Esq., of Henllys, says, after speaking of certain woods that had existed in times past, but were then destroyed: 'But, for the most part, those that dwell neere the cole, or that may have it carried by water with ease, use most cole fires in their kitchings, and some in their halles, because it is a ready fiere, and very good and sweete to rost and boyle meate, and voyde of smoake where yet chymnies are.' It is, he adds, 'called stone cole for the hardness thereof,' 'and being once kindled giveth a greater heat than light, and delighteth to burn in darke places.' 'Is not noysome for the smoake nor nothing soe lothsome for the smell as the ring cole is, whose smoake annoyeth all things neare it, as fyne linen, men's handes that warm themselves by it; but this stone cole yieldeth in a manner noe smoake after it is kindled, and is soe pure that fine camerick and laune is usually dried by it without any stayne or blemish, and is a most proved good dryer of malt—therein passing wood, ferne, or strawe. This cole for the rare properties thereof was carried out of this country to the citie of London, to the late Lord Tresurer Burley, by a gentleman of experience, to shewe how farr the same excelled that of Neucastell wherewith the citie of London is servid, and I think if the passage were not soe tedious there would be greate use made of it.' Such is the tribute to the excellent quality of stone coal afforded by this interesting old geologist. Two hundred and fifty years later, Taylor, in his 'Statistics of Coal,' writes of Welsh anthracite, after alluding to the slight use made of it: 'Yet, if we mistake not greatly, the day will arrive when this great metropolis (London) will seek from the mountains of Wales her supplies of a mineral fuel far preferable to that which from custom she now considers so valuable, and which, from its imperfect combustion, among other causes, now darkens the air with smoke, and pervades a vast and densely inhabited area with its sooty and noxious particles.' This prophecy is still unfulfilled—but in the presence of fogs hanging with increasing frequency like a funereal pall over the city—

raising the rates of mortality to an alarming extent, depressing the spirits and injuring the property of its inhabitants, it may well become a subject for earnest consideration whether some great alteration is not needed in our domestic heating arrangements, in cases where a population so vast and unprecedented is brought together. Our English prejudices fill us with the belief that comfort is alone to be found in an open grate and a blazing fire, around which we crowd in order to obtain some portion of the heat which finds its natural vent up the chimney; but is not this really prejudice or the result of habit? and would not the Canadian stoves, so much extolled by Mr. Hussey Vivian in his notes on his American tour, used with anthracite coal, afford a far more desirable and equable heat, and at the same time relieve the atmosphere from the masses of smoke now poured forth during the greater part of the year from every chimney in London, and render it as pure and clear as that which pervades the great anthracite-consuming city of Philadelphia?

Canadian or other stoves are moreover not essential for the use of stone coal for domestic purposes. An ordinary grate, with brick sides and back, close bars and a fair draught, will afford as clear and cheerful a fire as can be desired.

From its maritime position, Pembrokeshire was enabled to take the lead in the supplies of this fuel. An outlet for the workings in the remaining and far larger portion of the coal-field (excepting such as mules and ponies could afford) was only provided through the formation of canals and railways.

Their construction has been as follows:—The Swansea Canal, from Swansea to Abercrave, made in 1796, now supplemented by the Swansea Vale Railway, worked by the Midland Railway Company; the Neath Canal, made in or about the year 1800, up the Neath Valley, from Swansea and Britonferry, the use of which is now in a great degree superseded by the Great Western Railway, with which is connected the Neath and Brecon line passing through Crynant and Onllyn; the Gwendraeth Valley Canal, now converted into a railway, formed in 1825 from the port of Pembrey to Pontyberem; and the Llanelly Railway, now owned by the Great Western Railway Company, from Llanelly to Cwmaman and Llandilo, constructed in 1840. These several arteries, with a line about to be made to Mynydd Maur, in Carmarthenshire, form a complete outlet for the entire basin, and a ready means of communication with the ports of Swansea, Neath, Llanelly, and Pembrey, and with all parts of the kingdom, and their formation marks the epochs when anthracite was enabled to enter the general markets.

The first attempt in this country, so far as I am aware, to use stone coal for steam navigation, was on board a little boat called the *Anthracite*, running on the Thames about the year 1835, but I have no records by me of the course or results of that experiment. In 1847 some 600 tons was supplied to the steam-ship *Washington*, belonging to the American line running from Southampton to New York. In this case a fan was used, and, under the influence of the magnificent fires afforded by stone coal so treated, she proceeded on her voyage with the best prospects of success; but within a few hours she was back at Southampton with her furnace bars utterly destroyed by the great heat. Recognising the necessity of employing artificial draught, and that under such circumstances some method was needed for the protection of the bars, Messrs. Kymer and Kirk, the proprietors of an anthracite colliery, took out a patent in

1847 for a water grate to effect the object in view, but after a series of experiments it was not found practically to do so.

In the years 1853–54 Messrs. McLarty and Co. employed anthracite in their steamers the *Livorna* and *Geneva*, trading between Liverpool and the Mediterranean ports, and apparently with great success. In this case no artificial draught was used, and they reported thus: 'The anthracite has proved to be a twofold saving—in regard to economy of space, and to a very large saving in the consumption. In the former, the average saving of stowage is 20 per cent., and in the latter, the reduction in consumption is from 40 to 50 per cent., according to the quality of the coal.

'Its great cleanliness and entire freedom from smoke we look upon as not the least of the benefits its use confers upon us.'

The general business of this firm was not, I believe, profitable, and consequently this successful exposition of the use of anthracite ceased to exist. Prior to this period Dr. Frankland had reported to Mr. Watney the result of his experiments with the 'Pump Quart' vein coal of the Gwendraeth Valley. He states 'that the coal possessed an evaporating power considerably greater than any other fuel yet examined, 1 lb. evaporating, under favourable circumstances, in this boiler, 12·43 lbs. of water.' He adds that the space occupied by a ton of this anthracite, as used for fuel, is less than that taken up by any other coal, and he furnishes a table showing the number of lbs. of water evaporated by 1 cubic foot of various coals as under:—

'Duffryn,' Welsh Steam Coal	565·02
Graigola " "	581·20
Nixon's Merthyr "	514·93
James and Aubrey's (Anthracite)	565·02
Sliverdagh "	618·58
Watney's "	742·36

Anthracite was also introduced and for some time used on board her Majesty's yachts *Fairy* and the *Victoria and Albert.*

The 'Times' of July 7, 1853, under the head of naval intelligence, and referring to the sailing of the *Victoria and Albert*, from Holyhead to Dublin, contains the following paragraph: 'Her Majesty and the Court, as well as the officers of the yacht, will have a more comfortable voyage this trip than hitherto, owing to the use of the anthracite fuel with Colonel Coffin's steam jets fitted to her furnaces, by which no smoke or ashes issue from the funnel, thus abolishing the nuisances of smuts in the eyes and on the clothes of all on deck, and covering the decks with the dust from the flues, which the ordinary coal throws upon them.' The *Great Britain* steamship, the *Royal Charter*, the *Faith* and other vessels were also at this time using anthracite with much success; but these vessels, I am informed by Mr. Vickerman, of Hean Castle, Pembrokeshire (alluding to the two first), 'passed into other hands, who were interested in steam coal collieries.' He adds, 'The royal yacht also used anthracite from these collieries in her Majesty's yachting days, and she was so charmed with the cleanliness that she forbade the use of any other fuel when herself aboard.' In no single case, however, has the use of this fuel continued, and the opinion long since entertained and expressed, that without artificial draught it will not be a permanent success, has been fully confirmed. Economy in consumption, saving in space, and other advantages are no doubt readily obtained, but not so *rapidity* in evaporation; and, further, it has been demonstrated that the fierce fire

and extraordinary heat evolved by stone coal under the influence of artificial draught, requires some means for the protection of the bars. I also venture to think that, as described by Dr. Percy in the extract from his work which I have already given, the property of decrepitation may, as he says, so seriously check the passage of air through a furnace that the desirability of conveying the draught by means of the bars themselves, to all parts of the fire, is very apparent.

With the view of meeting the several difficulties I have endeavoured to describe, Mr. R. W. Perkins (than whom no better authority upon matters connected with anthracite exists), in connection with Mr. F. H. Perkins and Mr. Joseph Williams, took out a patent in November 1876, entitled 'Improvements in and relating to furnaces for burning anthracite and other fuel,' the main features of which consisted in the employment of hollow perforated bars, through which the blast is forced by a fan, steam-jet, or other artificial means. In this way combustion is enormously accelerated, and at the same time the bars are kept perfectly cool by the current of cold air passing through them. I have myself seen a piece of paper inserted within a bar when the fire was at its hottest, and remaining unsinged for a very considerable time. With this appliance Mr. Perkins instituted a series of trials at the foundry of Mr. T. W. Williams, of Swansea, and he has favoured me with the following results:—

Duration of experiment, five hours, with ordinary furnace and chimney draught, which was good; coal used, 'Birch Grove Graigola'—

Evaporated 7·06 lbs. water to 1 lb. of coal, and 672 lbs. water per hour.

Coal used, 'Powell's Duffryn'—

Evaporated 7·83 lbs. water to 1 lb. of coal, and 745 lbs. water per hour.

The bars with this coal were much burnt.

With Perkins's bars, but no blast; coal used, anthracite—

Evaporated 7·94 lbs. water to 1 lb. of coal, and 594 lbs. water per hour.

Bars slightly heated, but not damaged.

With a fan and Perkins's furnace; coal used, anthracite, Hendreforgan 'Big Vein'—

Evaporated 7·98 lbs. water to 1 lb. of coal, and 960 lbs. water per hour.

Deducting steam used for fan, the result was 7·92 and 952, the bars remaining perfectly uninjured.

The above experiments were authenticated by Mr. J. F. Flannery, C.E., who was present on behalf of Mr. E. J. Reed, M.P.

A further series of experiments was made with Körting's steam-jet blower and Perkins's furnace, with the following results:—

Blower used No. 1; diameter of steam nozzle $\frac{1}{7}$th of an inch, full open; coal, Hendreforgan anthracite; duration of experiment 2 hours 15 minutes—

Evaporated 8·14 lbs. water to 1 lb. of coal, and 912·22 lbs. water per hour.

Same blower and coal; duration of experiment 3 hours 50 minutes—

Evaporated 8·62 lbs. water to 1 lb. of coal, and 819·13 lbs. water per hour.

During a portion of this trial the intervals between coaling were too prolonged, which diminished the rapidity of evaporation.

With No. 2 blower; diameter of steam nozzle $\frac{1}{5}$th of an inch; $\frac{1}{4}$ to $\frac{1}{2}$ open; duration of trial, 3 hours 16 minutes—

Evaporated 8·04 lbs. water to 1 lb. of coal, and 925·25 lbs. water per hour.

With same blower, $\frac{3}{4}$ths open; duration of experiment, 4 hours—

Evaporated 6·56 lbs. water to 1 lb. of coal, and 1203·78 lbs. water per hour.

With blower No. 2, full open; coal, anthracite 'big vein' (not the '9-foot,' called 'big vein' of the Gwendraeth Valley; duration of trial 2 hours—

Evaporated 6·59 lbs. water to 1 lb. of coal, and 1200 lbs. water per hour.

In the foregoing trials the pressure of steam was maintained at 40 to 45 lbs.

I may here mention that Perkins's furnace, with Körting's No. 1 blower, has been in use for the past two years under the boilers at the stationary engine belonging to the Metropolitan District Railway, and situated on the Thames Embankment at the Temple Station, close to the statue of the late Mr. Brunel, where it can be seen; and it has removed much inconvenience that they there experienced from great deficiency of draught, which I have no doubt Mr. Speck, the manager of the railway, will confirm. In February 1878 a patent was taken out by Mr. T. W. Williams, whose name I have already mentioned, the object of which is to apply a blower of a cheaper construction than Körting's, and to avoid the noise created by the latter. This he effects by the application of a steam-jet inserted into every alternate bar through a nozzle of about $\frac{1}{16}$th of an inch diameter. The furnaces thus constructed have given much satisfaction, both in the use of anthracite as well as other coal, effecting much economy in the cost of fuel, and they are in use in a large number of the most important works in this neighbourhood and elsewhere. These patents have been followed by one taken out by Mr. J. F. Flannery, in September 1878, for effecting still further improvements, having the same objects in view.

First. The conduction of the blast so that it may enter the bars where necessary from their length, or for its better application, or otherwise, at *both* ends.

Second. When a steam-jet blower is used, in lieu of inserting a jet into each bar, as in Williams' patent, he forms a blower in connection with each *pair* of bars. This lessens by half the number of nozzles, and is intended to make the blast more effectual, and at the same time to decrease the consumption of steam.

Third. By a hole in the bar at the end furthest from the entry of the blast, he expels any ash or refuse that might enter through the perforations, by means of the blast itself.

But for marine steam boilers there are objections to the use of steam blowers, the chief being the quantity of steam they require, and the waste of fresh water in the boilers, and consequently a fan or other blast is desirable. In reference to the application of anthracite to marine engines, a series of experiments was made last year on board the steam-

ship *Elephant*, belonging to Messrs. Penn & Son. Into the full details time will not permit me to enter—they are given in a paper read by Mr. Flannery before the Society of Naval Architects, and fully reported in 'Engineering,' on April 16, 1880. I may say, however, that they fully confirm the trials made at Swansea. Mr. Flannery concluded his paper in the following words: 'It would be superfluous to say that this coal, anthracite, should have very general adoption in Her Majesty's Navy, and on board yachts, on account of its cleanliness, economy, non-explosive character, absolute smokelessness and strength under transportation, along with the absence of deterioration in the tropics.'

For stationary engines, where there is ample grate-surface, and great rapidity of evaporation is not needed, stone coal requires but a good natural draught and proper stoking.

I need hardly say that it is used for the engines at all the anthracite collieries, and for thirty years by Messrs. Hall & Son, at their powder mills at Faversham. These gentlemen have been good enough to reply to inquiries I made of them in view of this paper, as follows:—

'We took to anthracite primarily on account of the absence of smoke and sparks, and it always satisfies us in this respect.

'No alteration in our furnaces was needed. Forty pounds of steam is our average, although some of our boilers work up to fifty pounds.

'We use no artificial draught. The distance between the fire-bars is, in the larger furnaces one inch, and in the smaller $\frac{5}{8}$ths; and we do not notice that they burn out faster. If the nominal price of North Country and Welsh coal is the same, we should say the latter is 25 % the cheaper of the two.'

Messrs. Pigou & Wilks have also used the same fuel at their Dartford powder mills, for the past five or six years, and I am favoured with information of a similar nature to the foregoing, in respect of their experience of it.

I had intended alluding to the use of anthracite in the manufacture of iron; but I fear my paper has already exceeded the limits to which I am entitled, and the subject is too large and interesting to be dismissed in a few brief sentences. I can but hope that I have said enough generally with respect to this fuel, to show the great desirability of increased attention being paid to it. Quoting the words of Mr. Hussey Vivian—'We possess the finest anthracite in the world, and it lies almost untouched.'

Its advantages as a steam-raising fuel are undeniable, and not less so are those it presents for domestic and general purposes, where, as in London and other great cities, the absence of smoke would so greatly minister to the health and happiness of the inhabitants. I believe there is here a field worthy of the attention of scientific men, whose duty and privilege it is to render the products of the earth available for the benefit of mankind.

Report on the Present State of our Knowledge of the Crustacea. *By* C. SPENCE BATE, *F.R.S.*, *&c.*

PART V.—ON FECUNDATION, RESPIRATION, AND THE GREEN GLAND.

COPULATION of the crayfish takes place, according to the observations of M. Chantran,[1] during a period which includes the months of November, December, and January. The male seizes the female with his large nippers, turns her over, and whilst he holds her lying on her back, places himself in such a manner as to pour out the fecundating material upon the two outer lamellæ of the tail. After this first operation, which lasts some minutes, he conveys her rapidly beneath his pleon, in order to effect a second deposition of semen upon the plastron round the external opening of the oviducts, by means of the curious mechanism so accurately described by M. Coste, upon the plates of the caudal fan (*Ripisura*).[2]

According to the degree of the maturity of the ova at the time of the union of the sexes, oviposition takes place at a period varying from ten to forty-five days after copulation. At the moment when this function is about to be performed, the female raises herself upon her feet, and her pleopoda secrete for several hours a very viscous greyish mucus; and then she lies upon her back and brings up her tail upon her plastron in such a manner as to form with her pleon a chamber, as has also been observed by Lereboullet, in which the ova are collected, enclosing the aperture of the oviducts, the wall of which secretes a viscous fluid intended to fasten the eggs to the pleopoda during incubation. When things are in this state, the laying of the eggs takes place. It is effected at once, usually during the night, rarely during the day. 'In different females this expulsion lasts from one to two hours. The ova, which are always turned so as to present their whitish spot or cicatricula above, as if to receive more easily the influence of fecundation, are thus immersed in the greyish mucus, which in a manner binds the pleopoda and the margins and extremity of the telson to the pereion, and which assists in bounding the pouch or chamber so formed, in which a certain quantity of water is enclosed with the ova and mucus. Immediately after the oviposition we may detect in this mucus and water the presence of spermatozoids, precisely similar to those which are contained in the spermatophores attached to the plastron, and derived from them. With them are mixed pale yellowish drops and a certain number of rounded granulated globules, isolated or united in little masses, which do not exist in the cavity of the spermatophores, when spermatozoids are to be found. These spermatozoids are thus in direct contact with the ova, and in the midst of the vehicle which facilitates their penetration. Fecundation, then, is accomplished in this chamber—that is to say, outside of the genital organs of the female.'

The observations of M. Chantran have been corroborated by M. C. Robin, who has 'seen that the spermatozoids, which are found in contact with the ova in the chamber I have just described, are similar to those seen in the genital organs of the males, and to those in the spermatophores

[1] *Comptes Rendus*, July 4, 1870, tome lxxi. pp. 42–45. *Ann. Nat. Hist.* 4th ser. vol. 6, p. 265.

[2] Ῥιπίς, fan; οὐρά, tail (fantail). Telson and posterior pair of Pleopoda.

attached to the pereion. They are in the form of flattened cells, with five to seven rigid immovable cilia starting from their contour, and with a barrel-shaped projection about their middle. During the first two days following the oviposition, these spermatozoids, which are very abundant around the ova and in the mucus, become spherical and pale and remain motionless; in the following days they wither, and also become smaller, darker, and irregular. Lastly, when, after the fixation of the ova, the excess of the mucus has completely disappeared, in consequence of the pressure exerted by the incessant contractions of the pleon (which takes place in a variable period, of from eight to ten days after the oviposition), those spermatophores which still remain attached to the plastron, consist of small, white coriaceous filaments, either isolated or mutually adherent; they no longer show anything but a central cavity, in which the microscope reveals only a few more or less withered spermatozoids. The wall of these spermatophores retains its thickness, and remains, as before, composed of a concrete, striated, tenacious mucus.' [1]

Incubation lasts about six months, and the hatching takes place in May, June, or July.

The first moult takes place ten days or thereabouts after exclusion; the second, third, fourth, and fifth moults take place at intervals of from twenty to twenty-five days, so that the young animal changes its integument five times within a hundred days, corresponding to the months of July, August, and September. The sixth, seventh, and eighth moults take place in the following May, June, or July. So that there are eight moults during the first year of the animal's existence: five in the second year, and two in the third, of which the first takes place in June, the second in September. From this time the young crayfish becomes an adult.

After this the moulting takes place once a year in females and twice in males, which M. Chantran considers explains why the latter are larger than the former, the growth being in proportion to the number of moults. In the adult males the first moult takes place in June or July, and the second in August or September. The single moult of the females occurs in August or September.

To effect its moult, the animal places itself on its side; with its head and back it raises its carapace, which swings like a lid upon its hinge; then when it has thus completely disengaged the anterior part of the body, it separates entirely from its old carapace by a sudden movement of the posterior part. This operation, which lasts about ten minutes, is favoured by the previous secretion of a gelatinous material between the two carapaces, which facilitates their disengagement.

Twelve hours after the moults the legs of the crayfish are sufficiently firm to pinch strongly. Twenty-four hours later they are completely hardened, the dorsal surface remaining longer flexible; but at the end of forty-eight hours it has attained nearly a normal degree of consistency.

The young animal remains attached to the pleopoda of the parent for ten days after exclusion, when the first moult takes place. This is effected actually under the tail of the mother, and M. C. Robin has ascertained by means of the microscope, as shown by M. Chantran to the Academy, that the young remain suspended beneath the pleon of the mother by means of a hyaline *chitinous* filament, which extends from a point of the

[1] *Comptes Rendus*, January 15, 1872, tome lxxiv. pp. 201–2. *Ann. Nat. Hist.* 4th ser. vol. 9, pp. 173–4.

inner surface of the ovisac to the internal branch of each of the four lobes of the median membranous lamina of the caudal appendage. This filament exists when the embryos have only attained about three-fourths of their development.

If the young, continues M. Chantran, detach themselves before this period, they cannot live separately; but after the first moult they sometimes quit their mother and return to her again, up to the twentieth day, at which period they can live independently. He says (*Comptes Rendus* for July 17, 1871) he has observed that the young not only feed, while attached to the mother, upon the pellicle of the eggs, and the exuvia of the early moults, but the stronger ones eat those individuals whose development is rendered difficult by their agglomeration, and which cannot moult. Those which in moulting break their limbs are also devoured by their companions. Thus the crayfish which are ten days old eat each other, and this is moreover the case with those of any age when they moult and are too numerous for the small space they occupy beneath the pleon of the mother.

M. Chantran also has observed that temperature exerts a marked influence upon the duration of incubation and the number of the periodical moults between the exclusion of the young from the ovum and the adult period. The male becomes ready for copulation on entering its third year, and the female for fecundation at the commencement of the fourth year. In relation to the reproduction of the lost appendages M. Chantran's observations require confirmation, which he promised to make known. He says that the antennæ are reproduced during the period of a single moult. The other limbs are reproduced more slowly, three moults taking place during their regeneration. In the first year of their existence seventy days suffice for the reproduction of these limbs, while in the adult crayfish, the female requires three or four years to reproduce its limbs, and the male from a year and a half to two years, for the adult male moults twice a year and the female only once.

M. Gerbe, who has given much attention to the development of crustacea, says, none of those that he has observed has its organisation complete on its quitting the ovum as a *brephalus* (or larva), or possesses features identical with the parent, so that it might be referred to the species to which it belongs. All are furnished with transitory appendages adapted for natation, which give them a locomotion different from that of the adult stage. These appendages, he states, remain until the fifth and sixth moult, and become atrophied in position without falling off. It is not until the fifth or sixth moult that the general form of the adult external organs are complete. The *brephali* of various species, however they may resemble each other in external form, show minor features of distinction, such as a variation in the number and form of spots, and especially in the number and conformation of the plumose hairs and spines which fringe the extremity of the last segment of the pleon. These, he says, present definite characters which enable us to say to what species any particular brephalus belongs.

The stomach of the crustacea in the zoæa stage presents, he says, no solid pieces adapted for the grinding of food. It is furnished on its inner surface with stiff *spinules* arranged in rows, and with vibratile cilia like those found in the stomachs of a great number of the lower animals. These cilia communicate an incessant movement of rotation to the organic molecules upon which the animals feed.

In the brephalus of Palæmon, which we have carefully studied in a fresh and living state, we have not been able to detect any vibratile cilia within the stomach, but have observed that the outer wall has a strong and persistent power of contracting upon itself, and so forcing the contents of the stomach in a constant motion.

M. Gerbe (*loc. cit.*) also states that the liver consists of two simple cæca, one on each side, 'manifestly a diverticulum of the intestinal tube, with which it has wide communications; by ramifying it forms a hollow tree, at the base of which oscillate the vitelline globules, which the umbilical vesicle pours into the pyloric portion of the intestine.'

He also states that in whatever manner the respiratory functions may be performed in the adult crustacean, all have a tegumentary respiration in the brephalus condition, whether it be in the zoæa or megalop stage.

He has observed the brephalus of *Homarus* to possess a rudimentary branchial apparatus quite unfit to perform any functions, while the brephali of other genera are absolutely destitute of such organs, and some do not obtain them until after several moults.

This want of branchial respiration necessitates a distinction in the character of the circulation in the younger, as compared with that of the adult forms of crustacea, that is as between those that have none and those that have matured branchial organs.

In the brephali of *Maia*, *Porcellana*, *Crangon*, *Palæmon*, *Palinurus*, *Homarus*, *Cancer*, &c., the blood which the arteries have distributed to the different parts of the body returns entirely, directly to the heart, and this condition continues for a considerable time. 'It is,' he says, 'only after the third moult, in the most perfect brephalus of the species inhabiting our seas, that of the lobster, that a few globules are diverted from the original general circulation to penetrate into the nascent branchiæ. All the arteries open directly into the venous passages by an aperture more or less dilated into a trumpet-like form.

'In some larvæ the abdominal artery may present a sort of sphincter in its course, at some distance from the central organ of circulation; this, by contracting, temporarily suspends the flow of blood to the hinder parts.' This remarkable peculiarity exists not only in the larva of the lobster, but also in those of the *Porcellanæ*, and may be found most probably in the many other genera, as M. Gerbe has observed the circulation in the last somite of the pleon of the *brephalus* of *Cancer*, *Carcinus*, and *Palæmon* to have interruptions.

The same author states that, 'Although the transitory spines which arm the thorax' (carapace) 'of some species do not receive any arterial branch, a complete circulation is established in their cavity. Some of the globules which the venous lacunæ convey to the heart, make a digression into these transitory appendages, traverse nearly their whole length, and return by a parallel course into the lacuna from which they started.

M. Felix Plateau, of Ghent, has, through the agency of a graphic method, succeeded in obtaining a delineation of the heart's action in the crayfish. A curve is obtained, of which the ascending portions correspond to diastole, and the descending to systole, contrary to what obtains in the heart of vertebrate animals.

It is, he says, strikingly like the trace of the contraction of a muscle—a rapid, almost sudden ascent, with a flat summit, then a gradual descent, at first quicker, then slower. This, however, does not represent the whole truth; it is possible also to demonstrate a wave

affecting the muscular wall of the heart, and travelling from behind forwards, thus demonstrating that this condensed heart is a true dorsal vessel. On the stimulus of the entrance of renovated blood, it is only the hinder half or two-thirds of the heart that contracts immediately. This forces the blood into the anterior half, which contracts while the posterior division is dilating. When the temperature is increased, as a general rule the diastolic phase is abbreviated, the number of pulsations rising at the same time. M. Plateau has also succeeded in making experiments on the action of the cardiac nerve of Lemoine, an unpaired branch of the stomato-gastric ganglion. It is shown that excitation of this nerve quickens the pulsations of the heart and augments their energy, while the division of it lessens the heart's action. Whereas excitation of the pereionic ganglia always retards the heart's movements, being the converse of a similar treatment of the cardiac nerve.

M. Plateau likewise says that acetic acid applied to the heart-substance arouses its contractions even after they have ceased, and maintains them for several hours.[1]

M. Jobert, in the 'Annales des Sciences Naturelles,' 6th ser. vol. 4, has drawn attention to the character of respiration in the terrestrial crustacea of the decapod order. He says that in an examination of the anatomy of these animals we find that they are provided with branchia the same as other crabs both marine and fluviatile, and their habit of life in relation to these organs, which are essentially constructed for aquatic respiration, appears to be paradoxical, and has not escaped the attention of naturalists. In 1825 Geoffroy Saint-Hilaire suggested that the ridges which line the respiratory cavity of *Birgus latro* assisted the respiration—an hypothesis that in 1828 was combated by MM. Milne-Edwards and Andouin, who studied the respiratory cavity of the Gecarcinidæ, and attributed to a fold in the membrane which lined the internal cavity, the power of storing up a supply of water, with which it regularly laved the branchial apparatus, this water not serving respiration directly, but by its slow evaporation saturating with moisture the air which is brought into contact with the branchia, and so precluding the dessication of these organs.

M. Jobert has endeavoured to verify the correctness of these two opinions, and for this purpose has studied the habit of living specimens of *Uca*, *Gelassimus*, *Cardisoma*, *Grapsus*, *Telphusa*, and *Tylocarcinus*.

He takes as typical, *Uca una*, in which the respiratory apparatus is the most complete, and points out the various modifications which he has noticed among the other crustacea.

The branchial chamber is lined with a soft blackish grey membrane in continuity with the vertical septum (*cloison*). In a histological study of this membrane we find the elements of the hypodermic membrane of crustacea, for instance, large pigmentary cellules, special hypodermic cellules, and some peculiar fibres, either solitary or united in bundles in the form of X, which exist all over the membrane. This membrane is lined or covered by another very thin membrane capable of being separated from it by the aid of maceration in a very weak solution of acetic acid, and it appears to be a thin surface of chitin.

M. Jobert opened more than 200 specimens after having been confined for two, four, and six days in a perfectly dry place, and never found a drop of water, or ever found the surface of the branchia moist; the cavity was

[1] *Nature*, 1879, xix. 470.

always full of air, which the animal had not the power to expel, and even after submersion of the animal in water for three days some *Uca* had still a considerable quantity of air in the upper part of the branchial vaults. By the researches of Milne-Edwards and Andouin, we know that the arterial blood traverses vessels which become smaller and smaller, but is not taken up by the capillary veins, that it passes into some lacunæ in communication with the general cavity, and a portion of the branchiæ, and that after it has been revivified in these organs it is taken up by vessels which carry it into the pericardiac chamber, which is no other than an auricula: from thence into the heart. A coloured injection demonstrates if the canals of the respiratory membranes are arterial or venous. It also shows a network of extreme beauty that ramifies upon the vault, both on the internal and external parietes of the respiratory chamber. This network is regularly developed, and commences in a large sinus situated in the anterior part behind the orbital cavity. It divides into three vessels which ramify on the vertical septum (*cloison*), and another vessel of very large diameter which traverses the angle of connexion between the carapace and the lateral walls of the branchial cavity. Of the other vessels of less importance, one of which should be noticed, it curves and ramifies in the folded membrane described by Milne-Edwards and Andouin. All these vessels send forth a number of branches which resolve into capillaries that terminate in small irregular polygonal spaces, which are the true lacunæ; but from these lacunæ other equally delicate vessels take their departure. They may be observed to enlarge and open into still larger vessels, which still increase in size and open in their turn into a large trunk, which opens into an enormous sinus situated posteriorly to the pereion (or body of the animal) near where the pleon commences, about a centimètre within and above the basal portion of the last pair of feet. This large sinus traverses the vertical septum (*cloison*) and opens into the auricle.

A coloured injection forced into the sinus gives evidence of vascular network nearly symmetrical with that observed so regularly displayed on the walls of the respiratory chamber. Of these vessels one ramifies on the vertical septum, the other, which is of considerable diameter, winds upon the roof of the chamber. Another equally worthy of notice is situated in the angle of the internal membrane folded horizontally on the walls of the chamber.

There consequently exists, according to M. Jobert, in the parietes of the respiratory chamber a double system of vessels connected together by an intermediate capillary network inducing communication direct between the heart and the general cavity.

The air which is contained in the respiratory chamber never stagnates, but is renewed very regularly by the aid of a true movement of inspiration and expiration. The expiratory orifice of the chamber offers nothing very particular; whereas the inspiratory, in addition to that which is situated at the anterior part of the first pair of feet, is supplemented by others smaller but still important, situated between the third and fourth and posterior pairs, having the orifices externally hid by long hairs. It is to the vertical septum that the power belongs that induces the alternating movements of inspiration and expiration, and that under the influence of the central organ of circulation. In *Uca*, where the heart is of considerable size, we may observe at the period of the afflux of the blood into the cavity a corresponding movement outside the vertical septum which

separates the general cavity of the respiratory chamber, produced by a special mechanism.

M. Jobert found this respiratory chamber largest in *Uca Una*, the reflexion of the membrane most developed, the vascular vessels the most numerous. *Gelassimus*, he says, may be considered as possessing an organism nearly as perfect. Among the *Grapsi*, which live half of their time under water, the respiratory cavity is diminished by the flattening of the carapace, and the vascular network is less abundant.

Under all circumstances M. Jobert found a respiratory organisation similar to that which exists in all crustacea, but capable of undergoing a distinct usage. The organisation consists of a simple cavity, the membrane which lines it is furnished with vessels; one carrying deoxygenised blood, the other returning it to the heart without passing it through the branchiæ, after it has been brought into contact with air that has been incessantly renewed. Moreover, this membrane is covered by a pellicle which precludes desiccation and fulfils the part of a veritable epidermis.

In consequence of the observations which M. Jobert has made, he proposes to call the crustacea so organised by the name of 'Branchio-pulmonés,' in consequence of the capability by which their structure permits them to adapt themselves to atmospheric respiration, while they possess an anatomical arrangement that is essentially aquatic.

Professor Huxley has recently given much attention to the arrangement of the branchia in crustacea, and has done good service in suggesting a tabulation of them under a distinct nomenclature.

The position of the branchial plumes are constant throughout the several orders, and are absent or present according to specific or generic variation. He thus has proposed that each plume should be distinguished by a name that will at once recognise its position, and has proposed the following classification. The branchia that is rooted to the coxa of the several pairs of pereiopoda he calls *podobranchia*. The two that are situated on the articulating tissue that unites the appendage with the body of the animal, he calls anterior or posterior *arthropoda*, and the one that originates from the side or wall of the several somites of the pereion he calls *pleurobranchia*. To the long flabelliform lash that is so liable to vary both in form, size and number, he uses the two names proposed by Milne-Edwards for the same homotypical part, when attached to the organs of the mouth, or when appended to the feet, namely, the *Epignathe* and *epipodite*, an inconvenience that he himself has expressed when writing of the same in his work on the Crayfish. This, Milne-Edwards in his earlier works recognised by the title of the flabelliform appendage. It appears to me therefore that a term recognising the part in its true relation wherever existing will be found both more convenient as well as more correct in anatomical description. I have therefore elsewhere adopted for it the term of *Mastibranchia*[1] (branchial lash).

The same author has also proposed the classification of the macrura according to their branchial arrangement. But the study of a larger number of species is yet necessary, before we can see the advantage of placing in separate families, animals that in form and structure generally resemble each other, while others that are outwardly dissimilar are placed in the same genus.

During the voyage of the *Challenger* the lamented naturalist, Dr.

[1] Μάστις, lash; βράγχιον, gill.

Willemös-Suhm, investigated the metamorphosis of some crustacea which were repeatedly captured in the tropical and sub-tropical parts of the Pacific.[1]

Among these he obtained many specimens of Amphion, and of its brephalus (larva) not only of the true zoæa with a simple telson, but also of all the intermediate stages between it and the adult form, with two, three, four, five and six pairs of walking legs. Of the full-grown *Amphion* he had examined three specimens, two of which were undoubtedly males, as the testes and branchiæ were plainly visible, the former opening into the last pair of legs.

He was thus able to endorse Anton Dorhn's researches, wherein he dissected a full-grown specimen which possessed branchiæ and an ovary.

There is, he says, now no doubt that Amphion is not a larva, but that there are several species, and perhaps genera, of this remarkable form. For during the expedition they had captured two very interesting mature animals which are closely allied to Amphion. One of these has enormously long eye-stalks, being as long as the entire body of the animal. Another has, besides the long eye-stalks, the carpus of its several pereiopoda, very broad and paddle-shaped, while the dactylos is very minute. Both these forms, like *Amphion*, have a central ocular spot and eight pairs of legs, each supporting an ecphysis. But, as a whole, the animal is less flat and more resembles *Sergestes* than *Amphion*; and he states also that he has been able to determine that the form described by A. Dorhn under the name of *Elaphocaris* is the brephalus of a *Sergestes*. There is, however, one species, he says, which in the brephalus stage is not an *Elaphocaris*, but a larger and less spiny form, but similar in all other respects.

The manner in which *Elaphocaris* matures into the perfect *Sergestes*, he has been enabled to determine from the numerous specimens that he collected in the Western Pacific. After the first moulting the brephalus gets six more branched legs and loses many spines. It enters the *Amphion* stage, then moults, throws off the branched legs, gets branchia, and becomes a spiny *Sergestes*. It is only after this last moulting that the central ocular spot disappears.

He also observes that very similar to the development of *Sergestes* is that of *Leucifer*. The earliest form that he had obtained had no eyes, then sessile ones appear, and the animal then presents the form which Dana has called *Ericthina demissa*. After the second moulting the eyes are projected on stalks, and very long hairs are apparent on all the animal's appendages, and the animal appears a long and very delicate zoæa. It now enters the Amphion stage, but never gets more than four pairs of pereiopoda, and even loses a pair of these when it moults, and puts on the adult form of Leucifer, in which two pairs of pereiopoda are wanting.

It appears to me that instead of confirming the opinion of Anton Dorhn that Amphion is an animal in the adult stage, the observation of the accomplished naturalist of the *Challenger* rather induces one to believe that it is only a stage in the development of some of the Schizopod crustacea. The brephalus of Amphion, Sergestes, or Leucifer he has not been able to determine, inasmuch as he had never been able to obtain them. It is singular that Amphion was never taken excepting during the night.

M. Gerbe[2] says that the central nervous system of the larvæ of crus-

[1] *Ann. Nat. Hist.*, 4th series, vol. 17, pp. 162–3.
[2] *Comptes Rendus*, May 7, 1866, pp. 10–24.

tacea presents differences in its arrangement and form from that of the perfect individual, and the development of each of the medullary nuclei which constitute the ganglionic masses is in relation to the development of the organs to which these nuclei correspond.

Herr C. E. Wassiliew[1] has given an account of his investigations of the curious 'green gland' of the crayfish. He states that it consists of a single unbroken coiled tube, closed at one end and opening at the other into the sac of the gland or urinary bladder, and consists of three distinct portions. The first of these has the form of a somewhat triangular yellowish-brown lobule, lying at the upper surface of the gland and forming the blind terminal portion of the whole tube; the second forms a green cake-shaped mass, constituting the lateral and inferior parts of the gland; while the third is a long, white, coiled tube, connected at the end with the green portion and by the other opening into the bladder.

The entire tubular gland is lined by a single layer of epithelial cells, outside which is a fine structureless tunica propria, containing strongly refracting nuclei. There is no cuticular lining to the tube, which thus differs very markedly from the malpighian vessels of insects.

In the yellow portion the cells are sharply defined and convex on their inner surface. In the green part of the tube the cells are large, and their protoplasm is in connection with a peculiar network of pseudopodeal processes which extend into projections of the wall into the lumen of the tube. In the proximal portion (that nearest to the green section) of the white part of the tube the walls are smooth, and lined by small cells approximating the pavement form. In its distal portion mammiliform and dendritic processes of the wall project into the cavity, often giving the tube a spongy appearance, and the cells have long broad processes developed from their inner surfaces. The epithelium of the bladder agrees with that of the smooth portion of the tube.

The products of secretion are seen in the white and green, but not in the yellow portion of the gland, as yellowish, rather highly refracting, drops on the surface of the cells. Probably the yellow part secretes a substance soluble in alcohol. That part of the white tube, with the tesselated epithelium, most likely acts merely as a duct.

The anterior portion of the gland and bladder are supplied by a branch of the antennary arteries, their posterior portions by the sternal arteries; these break up into a rich network of capillaries in all parts of the gland. The nerve-supply of the bladder is also derived from two sources, its anterior part being supplied by a branch of antennary nerves (coming from the supra-œsophageal ganglion), its posterior part by a nerve from the supra-œsophageal ganglion, but no nerves have been observed in the gland itself.

This same green gland has been studied by Professor Huxley and Mr. Martin, who, in an elementary work on practical biology, describes it as a soft greenish mass lying on each side of the extreme front part of the cephalon, and that a fine bristle may be passed in through an aperture on the first joint of the antennæ. And in his more recent work on the crayfish, Professor Huxley accepts, with apparently little doubt, that the green gland is the representative of the kidney. 'The green gland,' he writes, 'is said to contain a substance termed *guanin* (so named because it is found in the *guano*, which is the accumulated excrement of birds),

[1] *Zool. Anzeiger*, 1, 1878.

a nitrogenous body analogous in some respects to uric acid, but less highly oxidated; if this be the case, there can be little doubt that the green gland represents the kidney, and its secretion the urinary fluid, while the sac is a sort of urinary bladder.'

The evidence on which this newly-proposed use of the green gland rests is the mild statement of Will and Gorup-Besanez (I quote from the notes in Professor Huxley's 'Crayfish' [1]), who say that in this organ and in the organ of Bojanus of the fresh-water mussel, they found 'a substance, the reactions of which, with the greatest probability, indicate guanin,' but that they had been unable to obtain sufficient material to give decisive results.

When we consider the position of this organ in its relation to the other parts, as they are arranged in separate genera, very definite analyses ought to be determined before a cautious anatomist can accept this idea as proven.

There is an osseous tubercle on the first joint of the antenna that is hollow, the orifice being covered by a thin translucent membrane, in the centre of which there is a narrow perforation. This tubercle Milne-Edwards and most carcinological students have thought to be the passage connected with acoustic properties, but which I have always contended was related to the olfactory sense; but as the observations of Will and Gorup-Besanez, although published in 1848, have been supported by Wassiliew in 1878, and Huxley in 1879, it will be desirable to allude to this tubercle by a name that will not commit its relation to any decided use until so determined. I shall consequently write of it as the *Phymacerite*.[2]

This organ is always in connexion with the coxa or first joint of the second pair of antennæ, even in those crustacea in which the antennæ are so fused into the frontal region (or metopus), that without previous knowledge it is impossible to determine its relation to the antennæ. In these cases, as in most of the higher types of the Brachyura, it is so concentrated into the animal that it is very generally covered and protected by the appendages of the mouth, and it is always closely associated with that organ. Moreover, the watery sac is so delicate in its structure that it is difficult to dissect it without rupturing its walls—a circumstance that I have never succeeded in doing in the Brachyura—and the passage of an inserted bristle must puncture its walls at any point.

In the Amphipoda the entrance is through a long spine, and the membranous passage is slightly winding. In the Isopoda I never observed any, at least conspicuous, tubercle. In the Brachyura it is generally closed by an osseous operculum.

Writing on this same organ, Milne-Edwards says: 'The Crustacea, or at least those of the higher orders, possess also the sense of hearing; the experiments of Minasi, as shown by a number of daily observations, furnish proof that, among a great number of these animals, there exists an apparatus that appears to be the seat of this faculty.

'This organ is situated on the inferior surface of the head, in advance of the mouth, and behind the second pair of antennæ, or even in the basilaire joint of the antennæ itself. In the crayfish, as exhibited by the researches of Scarpa, it exists at this place on each side of the body—a little osseous tubercle (*Phymacerite*) of which the summit presents a circular orifice which is closed by a thin, firm, and elastic membrane,

[1] *Gelehrte Anzeiger d. k. Baienschen Akademie*, No. 233, 1848.
[2] Φῦμα, tubercle; κέρας, horn (antennal tubercle).

which may be compared to a tympanum, or "à la membrane de la fenêtre du vestibule des animaux supérieurs" (Pl. XII. fig. 11 and 11 bis). Behind this membrane, at the base of the tubercle, we find a little membranous vesicle full of an aqueous fluid, which receives on the inner and upper surface a nervous filament given off from the antennal branch. Moreover, it is capped by a spongy mass, of which Scarpa makes no mention, which appears to be well adapted for an organ of hearing, although some narrow bands unite it to the organ of which we are about to speak (Pl. XII. fig. 9*a*). It is this organ which has already been considered as connected with the sense of smell. In the Langouste (Palinurus), in the centre of the membrane that closes the aperture of the antennal tubercle (*Phymacerite*) is a small opening which communicates with a disc-like organ (l'organe en form de galette) the object of which is doubtful, and for the most part among the Brachyura is entirely replaced by a small osseous, more or less movable, disc. In Maia and some other short-tailed crustacea, the disposition of this kind of operculum is very curious; we have ascertained, M. Andouin and myself, that on the anterior border there exists a tolerably large osseous plate which is bent at right angles and directed upwards towards the organ, and forms a disc that terminates in a point; near its base this lamellous prolongation is pierced by a great oval foramen, and this kind of opening is closed by a thin elastic membrane which we shall call the internal auditory membrane, and near which the auditory nerve appears to terminate. Fasciculi of muscles are attached to the extremity of the osseous lamella, which comes from the opercular disc of the auditory tubercle (*Phymacerite*), and which by its form resembles the stirrup of the human ear; finally, upon the anterior border of the external opening which is closed by this disc, there exists also a little osseous plate which is parallel with the internal auditory membrane, and when the anterior muscle of the ossicle contracts, so as to be slightly thrown back, all the little apparatus before the membrane to which we allude becomes more and more extended.

'After the researches made on the transmission of sound by M. Savart, we know that the existence of an opening closed by a thin elastic membrane is a condition most available for the increase of the power of hearing delicate sounds. This savant has observed that pieces of cardboard which are not susceptible to vibration so as to determine the form of regular figures in the fine sand placed upon the surface, are capable of so becoming when they were covered with a membranous disc. It is then to be presumed that the kind of drum that we now describe as that of the external auditory membrane of the crayfish, serves to communicate to the auditory nerve the vibrations that are transmitted to it, and which affect but little or nothing the sounding parts that are not in direct communication with these membranes. The mechanism by means of which the internal auditory membrane can be alternately relaxed or extended is analogous to that which is produced in the human ear by the action of the chain of ossicles, which traverses the cavity of the ear, and its effects may be supposed to be of the same kind. It serves to augment or diminish the undulations which strike the vibrating membrane, and to modify the intensity of the sounds which strike the ear.'

That this organ is not connected with hearing is now, I believe, accepted by those who have inquired into the subject, since organs resembling otolithes have been found in the coxa of the first pair of antennæ, and in the inner ramus of the posterior pair of pleopoda.

The green gland in Palinurus is very large, and I have been subjecting it to examination as to its form and structure, as well as placed the secretion contained in the sac connected with it in the hands of an expert chemist, but the results have not sufficiently progressed to enable me to embody them in this report.

Report on the best means for the Development of Light from Coal-Gas of different qualities, by a Committee consisting of Dr. WILLIAM WALLACE (*Secretary*), Professor DITTMAR, *and* Mr. JOHN PATTINSON, *F.C.S., F.I.C. Drawn up by* Mr. PATTINSON.

PART II.

THE first part of this Report, which was presented at the meeting of the British Association in 1878, had reference chiefly to the use of cannel gas such as supplied in most of the towns of Scotland, and which has an illuminating power equal to 26 candles when burned in a union-jet burner at the rate of 5 cubic feet per hour and under a pressure of 0·5 inch. It also pointed out the best means known of burning this quality of gas, and gave the results of photometric testing of several kinds of burners under varying conditions of pressure.

It is the object of this second part of the Report to give similar information regarding the burning of what is known as common gas, or gas made from the common bituminous coal of the Newcastle and other coal-fields, or from this class of coal mixed with a small quantity of cannel coal, and having an illuminating power equal to 16 standard sperm candles when consumed at the rate of 5 cubic feet per hour in Sugg's No. 1 London Argand Burner—the standard burner adopted in London by the London Gas Referees, and prescribed in nearly all recent Acts of Parliament of gas companies. This quality of gas, or gas varying from 14 to 16 candles illuminating power, is chiefly used in London and in most towns in England and Ireland.

The principal condition to be observed, in order to develop the maximum amount of light from coal gas, is to supply the flame in *a suitable manner* with just a sufficient amount of air to effect the complete combustion of the gas. If coal gas is lighted as it issues under a low pressure from the end of a gas pipe from which the burner has been removed, it burns with a long, irregular-shaped flame, giving off much smoke, and yielding a dull yellowish light of very little intensity. The gas has to ascend to a considerable height before it meets with sufficient air to consume it completely, and the upward currents created by the heat waft the languid flame about in all directions and cause it to give off smoky particles. On the other hand, if the gas is forced under considerable pressure through a very small orifice or very narrow slit, it burns with a thin bluish flame, without visible smoke, and yielding very little light. The small, rapid stream of gas, by virtue of the force with which it issues, becomes mixed at once with such an excessive amount of air that the carbonaceous constituents of the gas, instead of being partially separated and made incandescent, are converted at once into carbonic acid in a flame having little or no luminosity, just as when gas is burned in a Bunsen burner. These illustrate two cases in which air is supplied to the flame in an un-

suitable manner, one in which air is supplied too slowly, and the other in which it is too rapidly mixed with the gas. As in flat-flame burners the air supply is chiefly regulated by means of the pressure under which the gas is allowed to issue, it is necessary to avoid these two extremes in order to develop the light-giving properties of the gas. The dimensions of the orifice through which the gas issues from such burners, and the velocity with which it issues, should be so adapted to each other that the gas in burning is brought into contact with air in such a manner that the heat developed from a portion of the burning gas heats the remainder to a high state of incandescence before it is ultimately entirely oxidised. The quality of a flat-flame burner depends almost entirely on the extent to which this condition is fulfilled. In Argand burners, or at any rate in those of the best construction, the due supply of air is admitted to the interior and exterior of the cylinder of flame, and regulated by means of the chimney and cone, the gas being allowed to issue from the burner under little or no pressure. A more complete control is thus obtained over the air supply than is possible in the case of flat-flame burners, and it is probably on this account that more light can be developed from common gas when burned in good Argand burners than when burned in ordinary quantities in flat-flame burners.

The effect of the pressure under which gas is caused to issue upon the air supply, and consequently upon the amount of light emitted, is shown in the following results of experiments made with union-jet and batwing burners having orifices of various dimensions and unprovided with any means of checking pressure. The gas was caused to pass through them under different pressures applied by means of a weighted gas-holder.

The gas used was equal to 16 candles when tested with the standard burner—Sugg's No. 1 London Argand.

Union-Jet Burners.

Pressure of gas in inches	Cubic feet of gas used per hour	Illuminating power in standard candles	Illuminating power per five cubic feet of gas per hour
No. 1, with holes 0·024 in. diameter.			
0·5	1·6	1·0	3·1
1·0	2·5	1·2	2·4
1·5	3·2	1·2	1·9
No. 3, with holes 0·032 in. diameter.			
0·3	1·3	1·8	7·0
0·5	2·5	3·4	6·8
1·0	3·8	4·4	5·8
1·5	5·1	5·0	4·9
No. 6, with holes 0·043 in. diameter.			
0·2	1·2	1·8	7·5
0·3	2·0	3·7	9·2
0·5	3·8	7·3	9·6
0·7	4·7	8·8	9·2
1·0	6·0	10·2	8·5
1·5	8·1	12·0	7·4

Batwing Burners.

Pressure of gas in inches	Cubic feet of gas used per hour	Illuminating power in standard candles	Illuminating power per five cubic feet of gas per hour
No. 2 burner, with slit 0·008 in. wide.			
0·3	0·8	1·0	6·3
0·5	2·0	4·0	10·0
0·7	2·8	5·7	10·2
1·0	3·8	7·3	9·6
1·2	4·4	7·6	8·6
1·5	5·4	9·0	8·3
No. 4 burner, with slit 0·012 in. wide.			
0·3	1·3	2·7	10·4
0·5	3·2	7·6	11·9
0·7	4·3	10·1	11·7
1·0	5·6	12·6	11·3
1·2	6·4	14·0	10·9
1·5	7·7	16·4	10·6
2·0	9·0	17·5	9·7
No. 6 burner, with slit 0·014 in. wide.			
0·3	1·4	2·6	9·3
0·5	3·7	9·5	12·8
0·7	4·7	12·7	13·5
1·0	6·1	15·7	12·9
1·2	7·0	17·7	12·7
1·5	8·5	19·5	11·5
2·0	Flares		
Another batwing, with slit 0·020 in. wide.			
0·4	3·2	9·1	14·2
0·6	5·7	17·2	15·1
0·8	7·1	22·6	15·9
1·0	8·3	27·0	16·3
1·2	9·3	30·8	16·6
1·4	10·2	32·0	15·7
1·6	11·1	33·0	14·9
1·8	11·8	34·0	14·4
2·0	Flares		

It will be seen that the small quantity of gas passing through No. 1 union-jet becomes so mixed with air that even at 0·5 inch pressure the light emitted when burning 1·6 cubic feet per hour is only equal to one candle, or 3·1 candles when calculated for 5 feet consumption of gas. When the pressure is increased to 1·5 inches the results are still worse, for 3·2 cubic feet of gas per hour are burned with the production of light equal to 1·2 candles, or only 1·9 candles per 5 cubic feet of gas. With the larger sized union-jets the results are better, No. 6, when consuming 3·8 cubic feet of gas at 0·5 inch pressure giving a light equal to 9·6 candles per 5 feet of gas. This amount of gas—3·8 cubic feet—when issuing under 0·5 inch pressure is not mixed with so much air as the 3·2 cubic feet issuing under a pressure of 1·5 inches from the No. 1 burner.

The effect of the increase of pressure on the air supply, and consequently on the light produced, is also seen in the results of the experiments with the batwing burners. If the result of burning 5·4 cubic feet of gas

issuing from No. 2 batwing under a pressure of 1·5 inches is compared with the result of burning the amounts of gas nearest to this amount in the case of each of the other burners, it will be seen that the illuminating power increases as the pressure required to send the desired amount of gas through the burner decreases; or, in other words, the illuminating power is increased as the gas, issuing with less velocity, is thus mixed or brought into contact with less air. The following figures taken from the above table show this:—

No. of burner	Pressure of gas	Cubic feet of gas used per hour	Illuminating power in standard candles	Illuminating power per 5 cubic feet of gas
2	1·5	5·4	9·0	8·3
4	1·0	5·6	12·6	11·3
6	0·7	4·7	12·7	13·5
Large	0·6	5·7	17·2	15·1

It will also be observed, in examining the above tables, that in the case of each burner there is a certain consumption and a certain pressure which gives the best result, and that at all other consumptions and pressures above or below this the results are worse. No. 6 union-jet, for instance, gives the best result when consuming 3·8 cubic feet of gas under 0·5 inch pressure; No. 2 batwing gives the best result when consuming 2·8 cubic feet under 0·7 inch pressure; No. 6 batwing the best result when using 4·7 feet of gas under a pressure of 0·7 inch, and the large batwing, when using 9·3 cubic feet of gas under a pressure of 1·2 inches. There is, therefore, a limit to the reduction of pressure, causing an increase of the illuminating power of the gas consumed, and this limit is reached when the flame ceases to have a somewhat definite form, and burns in a languid, waving manner, showing very low intensity of combustion, and having a tendency to smoke. In such cases the air is not supplied sufficiently for vigorous and intense combustion. This condition is illustrated in the above tables, and especially in the case of the batwing burners. With each of these burners the gas issuing under the lowest pressures used produced less light than when higher pressures were used. Thus, for instance, No. 6 burner gives a light equal to only 9·3 candles per 5 cubic feet when the gas issues under a pressure of 0·3 inch, which is increased to 13·5 candles per 5 cubic feet when the pressure is increased to 0·7 inch. Again, with the large batwing having a slit 0·020 inch wide, the gas issuing at a pressure of 0·4 inch gives light equal to 14·2 candles per 5 cubic feet, whilst under a pressure of 1·2 inches the gas yields a light equal to 16·6 candles per 5 feet, a result even better than the standard testing burner gives.

Another point to be noticed in the above tables is, that as larger burners are used, and larger quantities of gas burned, the illuminating power per 5 cubic feet is increased. Although the chief cause of this improvement is the better apportionment of the gas supply to the air as regulated by the pressure, yet the increased volume of flame causing greater intensity of combustion, and preventing the cooling of the flame by the surrounding atmosphere, is doubtless another cause producing this improved result.

It has often been asserted that if gas be heated before it is burned,

the illuminating power is improved, and some experiments made in the laboratory of the University of Munich go to show that an increase of 18 per cent. in the illuminating power was produced by heating the gas from 64½ degrees to 288 degrees Fahrenheit. The London Gas Referees, in an able report on the construction of gas-burners, issued in 1871, repeated this experiment, and found no appreciable difference in the illuminating power of gas on heating the gas before burning from about 68 degrees to 296 degrees Fahrenheit. One of us has recently tried the same experiment. The gas was caused to pass through about 6 feet of copper tubing, heated to dull redness. By this means the gas was heated from 58 degrees up to 350 degrees, as indicated by a thermometer placed in the current of the gas within 6 inches of the burner. It was found necessary to open wider the tap of the meter as the temperature rose, in order to pass exactly the required quantity of 5 cubic feet per hour, the heated and expanded gas requiring more time to pass through the burner than the same quantity of cold gas. Careful observations were made of the illuminating power as the temperature rose. The result was that no appreciable difference could be seen in the illuminating power even at the highest temperature reached—350 degrees Fahrenheit—thus confirming the results obtained by the London Gas Referees. As the temperature of combustion would be increased by heating the gas, and consequently a higher degree of incandescence produced, some increase of the illuminating power may be expected, but the increase of temperature tried (and it is very difficult to heat the gas even so high as 350 degrees) is evidently too insignificant to produce any appreciable increase in the illuminating power.

An experiment to try the effect of heating the air supplied to the burner was more successful in producing an appreciable improvement in the illuminating power. The air was supplied from a holder under pressure. It was passed through a heated copper tube, and from thence into the bottom of the standard Argand burner, which was closed, excepting to the admission of the heated air. A thermometer was fixed in the current of heated air about 6 inches from the burner. There was no difficulty in heating the air to a temperature of 520 degrees Fahrenheit. At this heat the soldering of the apparatus gave way, so that no higher temperature was tried. The temperature of the unheated air was 70 degrees, and the gas used, when supplied with air of this temperature, gave a light equal to 16 candles per 5 cubic feet per hour. As the temperature of the air was increased, the illuminating power gradually rose, until at 520 degrees a light equal to 17·5 candles was produced—a rise of a candle and a half, or about 9 per cent., for an increase of 450 degrees in the temperature of the air supply. As the amount of heat supplied by the heated air brought into contact with the gas and the flame is considerable, an appreciable effect is produced on the temperature of the flame, and consequently on its illuminating power. It would appear, however, that the principle of heating the air supply is not likely to be adopted for general lighting purposes, for the additional light which any practicable amount of heating would cause to be obtained would probably not compensate for the extra cost and trouble attending the use of the required apparatus.

A number of burners of various kinds, now supplied to the public, have been tested with common coal gas, having an illuminating power

equal to 16 standard sperm candles, when burned at the rate of 5 cubic feet per hour in Sugg's No. 1 London Argand Burner, and the results obtained are given in the following tables. The standard candle, as in the case of cannel gas, is one consuming 120 grains of sperm per hour. The photometric apparatus and the method of testing employed were about the same as those described in the first part of this report. The two jets representing the candles were supplied with gas from a separate gas-holder, always kept under exactly the same pressure. The gas consumed in the burners to be tested was also supplied from a separate holder, to which any required pressure could be readily applied. For comparison, the results obtained are calculated into the amount of light for a consumption of 5 cubic feet per hour in each case.

Of the four classes of burners described in the first part of this report, the 'rat-tail' or single-jet burner is now seldom or never used for common gas for lighting purposes. The union-jet or fish-tail burner, the batwing burner, and the Argand burner, or modifications of these various burners, are now almost exclusively used. These burners and their modifications have for the most part been already fully described, and it is therefore unnecessary to repeat these descriptions at any length.

Messrs. Bray and Co. manufacture a great variety of flat-flame burners. Their 'Regulator' burner checks the pressure of gas in the mains by means of layers of muslin inserted in the burner. Their 'Special' burner, in addition to the layers of muslin, has also a piece of a kind of porcelain, containing a round hole of less area than the exit orifices, placed below the muslin, through which the gas passes into the burner. These 'regulator' and 'special' burners are made in three different forms—union-jets, batwings, and a modification of the batwing called a 'slit-union.' The latter, owing to a peculiar chambering out of the head of the burner, forms a narrower and higher flame than the ordinary batwing, and is therefore better adapted for use in globes. This form of batwing is also made by various other makers. Besides the burners already mentioned, Messrs. Bray and Co. also make each form of burner of high lighting power and of medium lighting power, and they recommend the medium lighting power burners in preference to the others for general use, as having less tendency to smoke.

Of these burners of Messrs. Bray & Co., the following have been selected for trial:—

Bray's Medium Lighting Power 'Regulator' Union-Jets.

No. of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
1	2·0	2·1	5·3	3·2	2·2	3·4	4·4	2·3	2·6
2	2·6	3·0	5·8	4·0	4·0	5·0	5·4	4·3	4·0
3	2·9	3·8	5·6	4·3	4·9	5·7	5·8	5·4	4·7
4	3·4	6·1	8·9	5·3	8·5	8·0	7·1	10·2	7·2
5	3·8	7·8	10·2	6·1	11·6	9·5	8·3	13·4	8·1
6	4·4	10·2	11·6	6·8	14·2	10·4	9·0	17·8	9·9
7	4·6	12·0	12·9	7·2	19·2	13·3	9·7	24·5	12·7
8	5·2	15·8	15·2	8·6	27·3	15·8	11·5	Flares	—

Bray's Medium Lighting Power 'Special' Union-Jets.

No. of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
1	2·1	3·0	7·1	3·1	4·2	6·8	4·2	5·0	6·0
2	2·3	4·3	9·3	3·7	6·5	8·8	5·1	8·0	7·8
3	2·5	4·6	9·2	3·9	6·5	8·3	5·3	8·1	7·5
4	2·9	5·7	9·8	4·5	8·6	9·6	6·1	10·7	8·8
5	3·5	7·6	10·9	5·2	11·8	11·3	7·0	15·2	10·9
6	3·6	8·6	11·9	5·8	13·7	11·8	8·0	17·6	11·0
7	4·2	10·6	12·6	6·6	17·6	13·3	8·8	23·2	13·2
8	4·5	12·8	14·2	7·3	22·5	15·4	10·1	31·0	15·3
9	4·8	13·6	14·2	7·7	24·0	15·6	10·4	32·5	15·6

Bray's Medium Lighting Power 'Special' Slit-Unions.

No. of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
1	1·9	3·9	10·3	3·1	6·5	10·5	4·2	8·9	10·6
2	2·2	4·4	10·0	3·5	7·6	10·9	4·9	9·8	10·6
3	2·8	6·5	11·3	4·5	11·0	12·2	6·1	15·6	12·8
4	3·0	7·2	12·0	4·9	12·8	13·0	6·6	17·2	13·2
5	3·3	8·0	12·1	5·3	14·4	13·6	7·3	19·4	13·3
6	3·8	10·2	13·4	6·2	17·4	14·0	8·3	23·6	14·2
7	4·1	11·0	13·4	6·6	19·1	14·5	8·9	26·0	14·6
8	4·8	13·4	13·9	7·6	23·5	15·5	10·4	32·0	15·4
9	5·3	15·2	14·3	8·5	26·0	15·3	11·4	37·0	16·2

Bray's High Lighting Power 'Special' Union-Jets.

No. of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
3	2·6	5·2	10·0	3·9	8·6	11·0	5·3	10·8	10·2
4	2·7	6·2	11·5	4·5	11·0	12·2	6·2	15·0	12·1
5	3·0	7·1	11·8	4·8	11·6	12·0	6·5	15·4	11·8
6	3·4	9·0	13·2	5·8	16·0	13·8	8·0	22·9	14·3
7	3·8	10·2	13·4	6·3	18·4	14·6	8·6	25·4	14·8
8	4·1	11·4	13·9	6·9	20·8	15·0	9·4	29·5	15·7

Bray's High Lighting Power 'Special' Slit-unions.

No. of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
4	3·2	8·0	12·5	4·8	13·6	14·2	6·4	17·8	13·9
5	3·2	8·2	12·8	5·1	14·2	13·9	7·0	19·5	13·9
6	3·5	8·8	12·6	5·7	16·0	14·0	7·8	21·6	13·8
7	3·9	10·6	13·6	6·4	18·4	14·4	8·8	26·0	14·8
9	4·8	13·2	13·8	7·9	25·2	15·9	10 8	34·5	16·0

Bray's High Lighting Power 'Special' Batwings.

No. of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
4	2·9	7·3	12·6	4·6	12·6	13·7	6·3	16·9	13·4
5	3·3	9·1	13·8	5·3	14·8	14·0	7·2	20·5	14·4
6	3·6	9·8	13·7	5·7	16·4	14·4	7·9	22·8	14·4
7	4·1	11·8	14·4	6·7	20·4	15·2	9·0	28·1	15·6

It will be noticed that in some of the union-jet burners the lower numbers of these give very poor results with common gas. It is only when Nos. 4 and 5 are reached, and with a consumption of about 5 cubic feet of gas per hour, that good results are obtained. As a rule, all the burners burn to greatest advantage when the pressure of gas is one inch.

Messrs. Bray & Co.'s Market Burner, intended, as its name implies, for use in the open air, also gives very excellent results from the somewhat large amounts of gas they consume. Two of these gave the following results:—

Bray's Market Burner—Batwing.

Mark of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
Market . . .	5·8	17·8	15·3	9·8	32·2	15·6	13·6	45·0	16·5
„ . . .	6·2	19·3	15·6	10·3	33·5	16·2	14·1	48·0	17·0

This firm has also recently manufactured some flat-flame burners of very large size, suitable for street illumination. These are made in an enlarged form of the slit-union pattern, and are called 'standard' burners.

Another form of street burner—a 'double-flame' burner—is made by them. This is formed by two burners being so placed that the flames from the two join together a little above the burner. We have not had an opportunity of testing the latter burners, but the large 'standard' burners have been tested with 16-candle gas at pressures of 0·5 inch, 0·8 inch, and 1·0 inch. with the following results, which, it will be seen, are higher than those obtained with the standard Argand burner:—

Bray's Large 'Standard' Burners for Street Lighting.

Mark of burner	At 0·5 in. pressure			At 0·8 in. pressure			At 1·0 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
30 Candle . .	11·0	37·1	16·9	15·0	49·3	16·1	19·0	60·8	16·0
40 " . .	12·7	43·2	17·0	18·4	60·8	16·5	21·2	72·0	17·0
50 " . .	15·0	48·8	16·3	19·3	65·6	16·9	23·6	80·0	16·9
60 " . .	13·3	44·2	16·6	18·3	60·8	16·6	23·6	77·9	16·5
70 " . .	16·0	52·5	16·4	21·9	73·6	16·8	25·0	84·8	16·9
80 " . .	16·5	55·0	16·6	22·7	74·9	16·5	27·2	87·7	16·1

Silber makes flat-flame burners in three forms—single, double, and triple batwings. A wedge-shaped piece of brass is inserted between the heads of the two latter burners, for the purpose of directing air currents to the flame. The body of the burners in each case is large and vase-shaped. The results obtained by testing these burners are given in the following table:—

Silber's Flat-flame Burners—Single, Double, and Triple Batwings.

Mark of burner	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
Single A . .	1·2	2·1	8·8	1·7	3·6	10·6	2·4	4·8	10·0
" B . .	1·3	2·8	10·8	2·1	4·6	11·0	2·7	6·0	11·1
" C . .	2·6	5·8	11·2	3·9	10·0	12·8	5·0	13·6	13·6
" D . .	3·2	8·0	12·5	5·1	14·1	13·8	6·5	18·3	14·1
" E . .	3·3	8·6	13·0	5·2	15·0	14·4	6·9	20·5	14·9
" F . .	4·2	11·6	13·9	6·3	19·0	15·1	8·2	25·0	15·2
" G . .	4·8	13·2	13·7	7·1	21·0	14·8	9·2	27·0	14·7
Double B . .	2·6	6·0	11·5	4·6	12·7	13·8	6·3	17·1	13·6
" C . .	3·3	7·4	11·2	5·4	16·2	15·0	7·5	22·0	14·7
" D . .	3·8	9·2	12·1	6·3	20·0	15·9	8·7	26·5	15·2
" E . .	4·3	10·0	11·6	7·0	22·3	15·9	9·5	31·0	16·3
Triple C . .	4·4	9·0	10 2	7·8	23·6	15·1	11·0	36·2	16·5
" D . .	4·9	7·9	8·1	8·2	22·5	13·7	11·5	38·0	16·5
" E . .	4·9	8·4	8·6	8·8	24·0	13·6	13·1	43·5	16·6

The double and triple burners do not give good results excepting at the higher pressures. The double ones give smoky sluggish flames at

0·5 inch pressure, and the triple ones smoky and shapeless flames even at a pressure of 1 inch.

Besides other flat-flame burners, Sugg has recently manufactured a large burner for large consumption of gas, which he calls a 'table-top' burner. This has a flat disc-shaped head with a semispherical centre, in which the slit is formed. Each burner is fitted with a governor. Two of these have been tested with the gas supplied to the governors at the under-mentioned pressures, and the following results obtained:—

Sugg's 'Table-top' Burners.

Pressure of gas in inches	Cubic feet of gas used	Illuminating power	Illuminating power per 5 cubic feet
0·5	3·8	10·0	13·2
1·0	6·2	18·6	15·0
2·0	8·3	24·8	15·0
3·0	8·4	25·2	15·0
	Another burner		
0·5	5·0	14·9	14·9
1·0	8·4	27·7	16·5
2·0	12·3	41·8	17·0
3·0	11·4	35·5	15·6

Brönner's burners, already described in the first part of this report, have also been tested. They are made specially for use for common gas, as well as for cannel gas. The A-top burners are intended for use in globes with common gas; and the B-top burners for use without globes, or in street lamps, also with common gas. The tops and bottoms of each burner are separately marked, and are interchangeable. The A-top burners are made with two sizes of tops and eleven sizes of bottoms. The B-top burners are made with eight sizes of tops and eleven sizes of bottoms. The following results were obtained with the A-top and B-top burners, using 16-candle gas:—

Brönner's A-Top Burners for Use in Globes.

No. of top	No. of bottom	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
		Cubic feet per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet per hour	Illuminating power	Illuminating power per 5 cubic feet
A 2	1	—	—	—	1·5	2·7	9·0	2·0	4·0	10·0
do.	2	1·6	2·9	9·1	2·4	5·2	10·8	3·1	6·8	11·0
do.	2½	2·0	3·9	9·8	2·9	6·8	11·7	3·8	9·4	12·4
A 3	3	2·1	4·4	10·5	3·2	7·8	12·2	4·4	10·6	12·0
do.	3½	2·5	4·8	9·6	3·8	9·2	12·1	4·9	12·2	12·4
do.	4	2·5	5·4	10·8	3·8	9·6	12·7	5·2	13·6	13·1
do.	4½	3·0	6·4	10·7	4·5	10·8	12·0	5·9	14·8	12·5
do.	5	3·2	7·7	12·0	5·1	13·2	13·0	6·8	18·0	13·2
do.	6	3·7	8·7	11·8	5·8	15·5	13·3	7·7	21·0	13·6
do.	7	3·5	8·6	12·3	5·9	16·0	13·6	8·4	23·0	13·7
do.	8	3·7	9·0	12·2	6·2	16·8	13·5	8·6	23·4	13·6

Brönner's B-Top Burners for Common Gas.

No. of top	No. of bottom	At 0·5 in. pressure			At 1·0 in. pressure			At 1·5 in. pressure		
		Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
No. 1 B	1	—	—	—	1·3	2·3	8·8	1·8	3·5	9·7
„ 2 B	2	1·3	2·3	8·8	2·1	4·4	10·5	2·8	6·4	11·4
„ 2 B	2½	1·6	3·0	9·4	2·5	6·0	12·0	3·4	8·4	12·4
„ 3 B	3	2·0	3·8	9·0	3·0	7·2	12·0	4·1	10·1	12·3
„ 3 B	3½	2·3	4·3	9·3	3·4	7·7	11·3	4·5	11·0	12·2
„ 4 B	4	2·3	4·7	10·2	3·6	8·8	12·2	5·0	13·0	13·0
„ 4 B	4½	2·7	5·9	10·9	4·3	10·4	12·1	5·6	15·0	13·4
„ 5 B	5	3·1	7·0	11·3	4·9	12·9	13·2	6·5	18·0	13·8
„ 6 B	6	3·8	9·6	12·6	5·9	16·4	13·8	8·0	23·0	14·4
„ 7 B	7	4·0	10·2	12·8	6·6	19·0	14·4	9·0	26·0	14·4
„ 8 B	8	4·7	11·8	12·6	7·3	22·0	15·1	9·6	30·0	15·7

Harrison's 'Gas-Light Improver' is a device similar to that of Scholl applied to union-jets. It consists of a small plate of thin iron placed across the top of the union-jet burner, against which the jets of gas impinge, thereby checking the force with which they mingle with the air. When the 'Improver' is applied to a burner with small holes, and when the gas issues under considerable pressure, the light results are better than when no 'Improver' is applied, but it produces no improvement if applied to a good burner of the same kind in which the pressure has been already checked.

Of Argand burners, those manufactured by Sugg and Silber have been tested. It will be seen that by carefully controlling and directing the air supply much better results can be obtained than with the Standard Argand used in testing. Each burner was tested with the consumption of gas to which it was best fitted, which was the largest quantity the burner will use without smoking.

The Silber Argand tried was one marked B. It was used with chimneys of various sizes, by means of which various quantities of gas could be consumed.

Silber's B Argand with various sized chimneys.

Size of chimney in inches	Cubic feet of gas used	Illuminating power	Illuminating power per 5 cubic feet
5 × 1¾	4·3	14·1	16·4
7 × 1¾	5·7	21·0	18·4
8 × 1¾	6·4	23·8	18·6
9 × 1¾	7·1	26·2	18·5
10 × 1¾	7·1	26·6	18·7

The following results were obtained in testing a series of Argand burners made by Sugg, which are called Sugg's New Reading Lamp Argand Burners. Each burner is fitted with a separate governor, to control the pressure of gas in the mains :—

Sugg's New Reading Lamp Argand Burners.

Mark of Burner	No of Holes	Size of Chimney	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
A	15	$6 \times 1\frac{5}{8}$	3·2	9·6	15·0
B	18	$6 \times 1\frac{5}{8}$	3·7	11·8	16·0
C	21	$6 \times 1\frac{5}{8}$	4·0	12·8	16·0
D	24	$7 \times 1\frac{3}{4}$	4·4	15·8	18·0
E	27	$7 \times 1\frac{3}{4}$	4·9	17·2	17·2
F	30	$7 \times 1\frac{3}{4}$	5·6	19·4	17·3
G	33	$8 \times 1\frac{3}{4}$	6·6	24·2	18·3
H	36	$9 \times 1\frac{3}{4}$	8·0	27·0	16·9
J	39	$9 \times 1\frac{3}{4}$	8·1	29·0	17·9
K	42	$9 \times 1\frac{3}{4}$	8·5	30·9	18·2

Sugg has recently produced some very large Argand burners for street lighting purposes. These are made with concentric rings, from which the gas is supplied. Two of these, one a hundred-candle burner, and the other a two hundred-candle burner, were tested with 16-candle gas, with the following results:—

Sugg's Large Street Argand Burners.

Description of Burner	Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
50-candle burner with two concentric rings	14·7	54·9	18·6
100-candle burner with two concentric rings and a centre jet . .	26·0	96·0	18·4
Do. do.	29·5	110·4	18·7
200-candle burner with three concentric rings and a centre jet .	52·0	196·0	18·8
Do. do.	55·0	220·8	20·0

Although a greater amount of light can be obtained from the burning of common gas in ordinary quantities in good Argand burners than can be obtained by the use of flat-flame burners, yet there are many reasons for thinking that the latter are better adapted for general use, and that they will continue to be much more largely used for general lighting purposes than Argands. In the first place, the first cost of the Argand burner is necessarily very much greater. The cost of maintenance—replacing broken chimneys, &c.—is also very much greater. Then, again, the cleaning of the chimneys is troublesome. They must be kept clean, or a loss of light will result. A chimney which had been in constant use for thirty hours, burning Newcastle gas, was so dimmed by the deposition of what is probably sulphate of ammonia on the inside, that half a candle of the light was intercepted. If, from the irregularities of the pressure of gas in the main or from other cause, a larger amount of gas is passed through the burner than can be thoroughly consumed, the flame gives off dense smoke, which, if not at once stopped, produces very disastrous effects in rooms. Hence it is almost absolutely necessary to use a special governor to each burner, which adds still more to the cost. It is only when the consumption of gas for which the Argand burner is specially

adapted is used, that the higher illuminating power results are obtained. With smaller amounts the loss of light by the excessive supply of air which then enters the chimney is much greater than in the case of flat-flame burners of good quality. On burning various quantities of gas through the standard Argand used for testing, the following results were obtained :—

Cubic feet of gas per hour	Illuminating power	Illuminating power per 5 cubic feet
2·5	2·5	5·0
3·0	5·0	8·3
3·4	7·9	11·6
4·1	12·1	14·8
4·5	14·3	15·8
5·0	16·0	16·0
5·5	17·8	16·2
5·7	17·8	15·1

By reducing the consumption of gas from 5 feet to 2·5 feet per hour, the illuminating power is reduced from 16 candles to 5·0 candles per 5 cubic feet.

The amount of light lost for illuminating purposes by the use of globes around the lights has been mentioned in the first part of this Report. In many cases this loss is considerable, and the use of globes with narrow openings, and made of very opaque white glass, should be avoided. The principal advantage of the use of globes is that the direct glare of the flames is prevented, and the light is softened and diffused in a pleasant manner. It is often worth the sacrifice of a portion of the light to produce this effect. With properly made globes of thin milk-white glass, having openings of not less than four inches at the bottom, and still wider ones at the top, the loss of light can be to a great extent avoided, the light being reflected by the white surfaces of the interior of the globe through the wide openings both upwards and downwards.

From what has been frequently shown in this report it will be seen how very important it is to have complete control of the pressure at which the gas is supplied to the burners in order to develop its light-giving properties to the best advantage. The first part of the report points out the various causes which give rise to great fluctuations of the pressure in the gas mains. In many towns the pressure may vary from less than an inch to four inches. No doubt the pressure as supplied to the burners can be regulated by the taps at the burners or at the meter, but in many situations where the pressure alters much in the course of a single night this is very troublesome to attend to, and in most cases will be neglected. It is best in such places to have governors which act automatically by the pressure of the gas.

Besides the various governors already mentioned suitable for a number of lights, it is now possible to obtain governors suitable to be applied to single lights at a cost within the reach of most gas consumers. These are placed near the burner, and in many cases form a part of the burner. In many situations subject to great variations of pressure it is worth while on the score of economy to adopt such burners. Vastly different amounts

of gas are passed, often imperceptibly, through the same burner. In most of the burners tested for the purposes of this Report, and which are not provided with means of checking the pressure, it will be seen that about twice as much gas is passed through the burner at 1·5 inches pressure as is passed through at 0·5 inch pressure, and the pressure in the mains often varies more than this. The amounts of gas passed through a burner without obstruction for checking pressure with and without a governor at different pressures is shown in the following table:—

Inches of pressure in the main	With governor. Feet of gas used per hour	Without governor. Feet of gas used per hour
½ in.	2·6	4·9
1 ,,	4·0	7·4
2 ,,	4·0	11·8
3 ,,	4·0	15·6

Single-burner governors are now made by Sugg, Peebles, Wright, Borradaile, and others. Many of these regulate the pressure by the rising and falling of a small cup or cone fitting loosely in a receptacle through which the gas passes on its way to the burner, and they are of a size which does not obstruct the downward light, and of a form which does not offend the eye. Several of these have been tested at pressures varying from half an inch to three inches. From the exigencies of their construction they do not act absolutely perfectly, but at pressures varying from one inch (at which most of them are constructed to commence to act) to three inches the amount of gas they allow to pass to the burner does not vary more than half a cubic foot per hour. Such governors are of very great service, not only in preventing waste of gas, but also in very nearly securing what is so essential to the development of the maximum amount of light, a uniform supply of gas to the burner.

Report of the Committee, consisting of Dr. GAMGEE, Professor SCHÄFER, Professor ALLMAN, *and* Mr. GEDDES, *for conducting Palæontological and Zoological Researches in Mexico. Drawn up by* Mr. GEDDES (*Secretary*).

IN pursuance of the plan for carrying on certain geological and zoological explorations in Mexico (of which I gave some account in my application for a grant from the Association last year), I sailed from Liverpool on September 10th, 1879, and arrived at the city of Mexico on October 10th.

Besides the general object of a naturalist's first visit to the tropics, that of obtaining a more general view of animated nature, I proposed undertaking certain specific researches:—

1. To examine some of the deposits of fossil bones in the Valley of Mexico, of which so many accounts had been given me by eye-witnesses, and to ascertain their age and contents.

2. To fill up such leisure as might remain from that inquiry with a study of the completely unknown microscopic life of the great lakes.

3. To make a general collection.

4. To dredge on the coast, should time allow.

I shall proceed to discuss in how far each of these parts of my programme has been carried out, but must first explain that almost immediately after my arrival in Mexico my health commenced to suffer; that indisposition soon passed into illness, and that this illness, aggravated by very severe, and as it afterwards turned out, mistaken medical treatment, confined me to my room for upwards of two months, and left me utterly enfeebled. After my recovery I remained more than a month in hopes of recovering strength and returning to work, and even attempted a few excursions, *e.g.* to the caves of Cacahuamilpa; but was at length compelled to yield to the urgent advice of my physicians and relatives, and return to Scotland to recruit my health. I therefore sailed from Vera Cruz on 1st March last. It will thus be readily understood that my results, gathered as they are from a period of a few weeks after my arrival (during which my time was largely occupied in the preliminary work of gathering information and improving my knowledge of the language, not to speak of failing health), are necessarily of the most imperfect kind, and that, of various undertakings, well begun, but never finished, nothing can be said at all. I hope, however, to make my memoranda useful to another explorer, my friend M. Joyeux-Laffuié, D.Sc., who proposes shortly to undertake a similar and I trust a more fortunate expedition to Mexico.

For dredging on the coast there was of course no time. I am convinced, however, that excellent results await the fortunate naturalist who can devote a winter to the task, particularly on the Pacific side, which is completely unexplored.

My collections, though small, were by no means valueless. I obtained a number of plants, mainly from the ravines eroded by streams in the alluvial of the Plateau, and these are of considerable interest, since many are of subtropical *facies*, belonging to a zone of vegetation considerably warmer and lower than the Plateau itself. This tends to throw some light upon the migrations of plants in these countries. The plants growing on the sides of ravines being protected from inclemencies of weather, better exposed to the sun, &c., are thus enabled to reach altitudes otherwise uninhabitable by them. I have presented these dried plants to the Herbarium of the Royal Botanic Garden, Edinburgh, where also some of their seeds are being grown.

My zoological collection is deposited in the British Museum. It consisted of a few mammals, of which two are of considerably rarity, viz.: *Spermophilus Mexicanus*, Licht., and *Blarina micrura*, Tomes; twenty-five reptiles, fifty-two fish, twelve crustaceans, and a few insects. Some of the reptiles, fishes, and crustaceans are of interest to the systematic zoologist, and a note upon some of the crustaceans has just been published by Mr. Miers in the 'Annals and Magazine of Natural History.' I was also able to provide Professor Huxley with a small collection of crayfishes and prawns.

The microscopical investigation, too, had commenced to yield results of interest. Although in autumn the general *facies* was surprisingly European, yet new and strange Protozoa, Rotifers, &c., were by no means rare.

Despite all hindrances, however, the main inquiry, as to the age and contents of the superficial deposits of the Plateau, came much nearer to a solution. The Plateau is covered to an unknown depth—so great that the

Artesian wells which are frequently bored never reach the bottom—with a series of lacustrine deposits, earthy, clayey, and sandy. Most frequently the alluvium contains a great quantity of pumice and volcanic ash, and then acquires so much consistence as to be used in the cheaper and less durable kinds of building. A considerable area is covered by lakes, Chalco, Xochimilco, Tezcoco, &c., and these, particularly the latter, have diminished greatly since the Spanish Conquest. The principal lake, into which all the others drain, *Tezcoco*, is very shallow, nowhere more than four or five feet deep, and has no definite limits, but alters its area by many square miles in the course of every season. It is easy to see that the various lakes now scattered over the Plateau are merely the remnants of one vast lake, whose shallow waters extended over the vast plain around the site of the City of Mexico, and which received the torrents which come down from the surrounding mountains every rainy season laden with detritus. Meanwhile the volcanoes, which are scattered over and around the Plateau, were in great activity, and the surface of the lake seems to have been generally either wholly or partly covered with pumice and ashes, which as the waters receded during drought would be deposited along with the mud at the bottom.

It is interesting to compare the lava-flows which have been emitted on what was at the time dry land with those which were formed in the lake itself. The former, such as the Pedregal de Thalpan, are dense, hard, and black, like the lava of Vesuvius; the latter, *e.g.* the two little hills near Mexico, known respectively as the Great and Little Peñon, are gigantic cinders, red, cracked and porous, and here and there containing large irregular caves, formed simply by the expansion of the included water into steam.

All over the Plateau, imbedded in the soft alluvium or in the denser '*tipitate*' as the rock containing pumice is called, and frequently laid bare by the streams, are to be found considerable numbers of mammalian skeletons. To examine and collect these I made a good many expeditions, generally accompanied by one or two Indians, who served as guides and excavators. I obtained many specimens, nearly all, however, in very imperfect preservation, and many so friable as scarcely to bear removal. The most abundant remains are those of *Elephas*. *Mastodon*, however, occasionally occurs, and skeletons of horses, buffaloes, and wolves are tolerably common. I was much interested by the fact that some time before and again during my visit a specimen of *Glyptodon*, apparently *clavipes*, had been found in the course of some engineering work, and had come into the possession of the museum there, thus establishing the range of this genus of Edentates into the northern part of the Neotropical region. I was fortunate in discovering a magnificent Edentate skeleton, closely resembling *Mylodon*; but, on returning with my workmen early next morning to continue the excavation, we found our specimen shattered into fragments. Some of the country people, who always watched one's movements with intense suspicion, and who alternately regarded us as treasure-seekers and as magicians, so adding considerably to the danger and discomfort of the undertaking, had done this, and we were able only to rescue a single broken tooth, now in the British Museum.

On my way home I examined, along with Mr. Halliday, C.E., of Vera Cruz, an artesian well which he was boring in hopes of obtaining a supply of water for that city. He had passed through 1260 feet of sands and

clays, and kindly gave me specimens of all the strata passed through. These, with his description, are at present in the hands of my friend, Dr. James Geikie, F.R.S., for transmission to Mr. Murray or some other specialist, from whom an account of their microscopic contents may perhaps be forthcoming at the next meeting of the Association.

Report of the Committee, consisting of the Rev. H. F. BARNES-LAWRENCE, Mr. SPENCE BATE, Mr. HENRY E. DRESSER (*Secretary*), Mr. J. E. HARTING, Dr. J. GWYN JEFFREYS, Mr. J. G. SHAW LEFEVRE, Professor NEWTON, *and the* Rev. Canon TRISTRAM, *appointed for the purpose of inquiring into the possibility of establishing a Close time for Indigenous Animals.*

YOUR Committee has to report that on the 7th of June last Mr. Dillwyn, M.P., obtained leave from the House of Commons to bring in a Bill to amend the Laws relating to the Protection of Wild Birds, which Bill was read a second time on the 14th, and ordered to be considered in Committee of that House on the 21st of June.

Owing to the late period at which the Bill was introduced, the rapid progress of its earlier stages, and the difficulty of communicating with some members of your Committee, an attempt to fix a meeting failed, and your Committee, as a body, had therefore no opportunity of discussing this Bill, nor, if need were, of reporting thereon to the Council of the Association according to its instructions. In their private capacity some members of your Committee, conceiving that the Bill contained much that was objectionable, are understood to have made representations to that effect to various members of the House of Commons whom they believed to be interested in the subject. The Bill passed through Committee of the House of Commons on the 21st of June, and, in consequence of the various amendments then adopted, assumed an entirely different aspect from that which it originally presented, several of the features believed to have been regarded by some members of your Committee as most objectionable having disappeared. In this state it was read a third time in the House of Commons, and was sent to the House of Lords on the 15th of July.

In the House of Lords charge was taken of it by Lord Aberdare, and it received very careful consideration, several important amendments proposed by him and by Lords Lilford and Walsingham being made in it, both in Committee and on Report, and it was read the third time on the 15th of August.

The Bill now awaits the approval of the House of Commons to the Lords' amendments.

Your Committee, for the reasons above assigned, having been unable to discuss this Bill, refrains from offering any remarks upon it, and, while trusting that the new measure may prove to be efficient, begs leave to submit this short statement of facts.

Report of the Committee, consisting of Professor DEWAR, Dr. WILLIAMSON, Dr. MARSHALL WATTS, Captain ABNEY, Mr. STONEY, Professor HARTLEY, Professor McLEOD, Professor CAREY FOSTER, Professor A. K. HUNTINGTON, Professor EMERSON REYNOLDS, Professor REINOLD, Professor LIVEING, Lord RAYLEIGH, Dr. SCHUSTER, *and* Mr. W. CHANDLER ROBERTS (*Secretary*), *appointed for the purpose of reporting upon the present state of our Knowledge of Spectrum Analysis.*

[PLATES X. AND XI.]

Contents.

§ 1. SPECTRA OF METALLOIDS. *By* Dr. SCHUSTER, *F.R.S.*

I. *Preliminary Remarks.*

CERTAIN spectroscopic changes and variations, which we now know to be common both to metals and metalloids, were first observed in the case of metalloids. It is owing to this fact that their spectra have given rise to so much discussion. Ångström and v. d. Willigen had examined electric sparks passing through various gases, and had thus observed the spectra of several metalloids; but the subject first received due attention when Plücker and Hittorf (1864) announced the important discovery that one and the same element can, under different conditions, show more than one spectrum.[1] Attempts were naturally made to disprove such a remarkable and at first sight improbable assertion. Different spectroscopists took different views; most metalloids were carefully examined, and in the long discussion which followed, each side had to give in on some points. Plücker's discovery, however, was established in the case of all metalloids which have been sufficiently well studied. There is now among those best able to judge a general agreement on the facts, although great differences exist as to their interpretation. We have in the present Report nothing to do with the explanations which have been offered to account for the variability of spectra, but only to record facts and to describe the phenomena which appear when the spectra of metalloids are examined under different and varying conditions.

It is perhaps advisable to say one word on the nomenclature which we shall adopt, and on the general appearance of the spectra with which we have to deal. Different spectra often resemble each other in general appearance, so that we can classify and roughly divide them into three kinds or orders: continuous spectra, line spectra, and spectra of fluted bands, or channelled-space spectra, as they are sometimes called. Plücker and Hittorf called the spectra of fluted bands, spectra of the first order; the line spectra, spectra of the second order. This nomenclature

[1] Both Plücker and v. d. Willigen had already, in 1858, described the band spectrum of nitrogen, but the subject was first thoroughly investigated by Plücker and Hittorf, and only received due attention after the publication of their paper.

is sometimes adopted; it presents no advantages, but, on the contrary, may give rise to a good deal of misconception. We shall not use the expressions. A spectrum is called a continuous spectrum when it extends over a wide range, and is not broken up into separate lines. It is, however, not necessary that it should extend through all the colours. We may have a continuous spectrum in the green without an admixture of red and blue, and we often have continuous spectra which are confined to one end of the spectrum, either to the red or to the violet.

The spectra of fluted bands or channelled spaces generally appear, when seen in spectroscopes of small dispersive power, as made up of bands, which have a sharp boundary on one side and gradually fade away on the other. When seen with a more perfect instrument, each band seems to be made up of a number of lines of nearly equal intensity, which gradually come nearer and nearer together as the sharp edge is approached. This sharp edge is generally only the place where the lines are ruled so closely that we cannot distinguish any more the individual components. The edge is sometimes towards the red, sometimes towards the violet end of the spectrum. Occasionally, however, the bands of channelled space spectra do not present any sharp edge whatever; but are simply made up of a series of lines which are, roughly speaking, equidistant. In small spectroscopes these bands appear to be altogether homogeneous, presenting a fairly sharp edge on both sides. A body, as we shall see, may have more than one spectrum of the same kind.

Variations in the spectra of gases are generally obtained by a sufficient alteration in the intensity of the electric discharge, which renders them luminous. We shall call the discharge which passes, when the electrodes are connected directly with the terminals of the induction coil, 'the ordinary discharge,' in contradistinction to the 'jar discharge,' in which each terminal is also connected with one of the coatings of the Leyden jar. In order to get the best effect with the jar discharge, it is generally necessary to interrupt the circuit in some part, so that a spark is forced to break through the air whenever the discharge passes.

II. *Nitrogen.*

Ångström: 'Pogg. Ann.' xciv. p. 158 (1855).
Plücker: 'Pogg. Ann.' cv. p. 76 (1858); cvii. p. 519 (1859).
V. d. Willigen: 'Pogg. Ann.' cvi. p. 618 (1859).
Huggins: 'Phil. Trans.' cliv. p. 144 (1864).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 1 (1865).
Brassak: 'Abh. Nat. Ges. Halle,' x. (1866).
Wüllner: 'Pogg. Ann.' cxxxv. p. 524 (1868); cxxxvii. p. 356 (1869); cxlvii. p. 325 (1872); cxlix. p. 103 (1873).
Salet: 'Ann. Ch. Phys.' xxviii. p. 52 (1873); C.R. lxxxii. p. 223: 274 (1876).
Ångström and Thalèn: 'Nov. Act. Ups.' (3), ix. (1875).

The Line-spectrum.—This spectrum appears whenever a strong spark (jar discharge) is taken in nitrogen gas. It is always present when metallic spectra are examined by the ordinary method of allowing the jar discharge to pass between two metallic poles. A good knowledge of this spectrum, which is very rich in lines, is important in all cases where an electric discharge is used for spectroscopic analysis. The spectrum has been studied especially by Huggins and Thalèn. The latter has

given the wave-lengths of all atmospheric lines, but has not separated the oxygen and nitrogen lines. Huggins' measurements have been reduced to wave-lengths by Watts (Index of Spectra). At atmospheric pressure the lines are not sharp, so that an exact measurement is difficult. Plücker and Hittorf have given a drawing of the lines as seen in vacuum tubes with jar and air-break; but they did not use a sufficient dispersion for accurate measurement, and their points of reference are so few, that the reduction to wave-length made by Watts was attended by many difficulties, and the result is not altogether satisfactory. A careful set of measurements of the nitrogen lines as they appear, when the pressure is low and with high dispersive power, would be a very useful addition to our knowledge of this spectrum. The continuous spectrum generally accompanying this spectrum has been investigated by Wüllner (1869).

The Band-spectrum of the Positive Discharge.—This spectrum which is generally called the band-spectrum of nitrogen, always appears when the discharge is sufficiently reduced in intensity.

It was first observed by Plücker (1858) in a vacuum tube, and about the same time by v. d. Willigen in the brush discharge of an ordinary electrical machine. The best way of obtaining it is that adopted by Plücker, who was the first to introduce the shape of vacuum-tubes now generally in use with the capillary part. Hence these tubes are often called Plücker's tubes. The capillary part increasing the resistance greatly increases the luminosity of the discharge. If nitrogen (or atmospheric air) be introduced into such a Plücker tube, the capillary part will shine, on reduction of pressure, with a rose-coloured light, when the ordinary discharge is sent through it. The spectrum is one of the most beautiful which can be observed. A very good coloured drawing of it is given in Plücker and Hittorf's paper. Accurate measurements of the bands are given by Ångström and Thalèn. Another drawing with measurements will be found in Lecoq de Boisbaudran's Atlas.[1]

The bands of this spectrum, which are situated in the red and yellow, present a different appearance from those which are seen in the blue and violet. This fact has led Plücker and Hittorf to the supposition that we have to deal with two different spectra which are superposed only but given out by two distinct sets of molecules. The authors tried and succeeded in separating the two spectra. By increasing the diameter of the capillary part they obtained a tube which only showed the red and yellow bands. Their experiment is described in the following words, which will be found in the 28th paragraph of the paper mentioned at the head of this chapter:—

'Thus we succeeded in constructing a tube which, when the direct discharge was sent through it, became incandescent with the most brilliant gold-coloured light, which might easily be confounded with the light of highly-ignited vapours of sodium; but with the intercalated jar, the light of the incandescent gas within the same tube, had a fine bluish-violet colour. The yellow light when analysed by the prism, gave a beautiful spectrum of shaded bands, extending with decreasing intensity to the blue, the channelled spaces being scarcely perceptible. The bluish light when examined was resolved by the prism into channelled spaces, extending towards the red; while the former bands almost entirely disappeared. We may transform each colour and its corresponding spectrum into the other *ab libitum.*'

[1] Lecoq de Boisbaudran, *Spectres Lumineux*, Paris (Gauthier Villars).

This experiment might not be considered to be altogether conclusive, as a mere relative increase of intensity in the violet end by an increase of temperature might not be considered sufficient evidence for such a wide distinction. It was, therefore, thought better to discuss these spectra together, and not to separate them, for there is no doubt that in the vast majority of cases they appear as one whole and not as two distinct spectra. It might, however, be adduced in support of Plücker and Hittorf's opinion that the general aspect of the spectrum in the green is certainly that of two overlapping spectra. Wüllner ('Wied. Ann.,' viii. p. 590), has described the gradual changes seen in a nitrogen tube having a very fine capillary bore, when the pressure is gradually reduced to a very small amount. Owing to the increase of temperature the spectrum gradually changes into a line spectrum, which is essentially the same as the well-known line spectrum of nitrogen. Wüllner's results will be discussed in a separate report.

The Spectrum of the Negative Glow.—The glow which surrounds the negative electrode in an exhausted tube shows in many gases a spectrum, which, as a rule, is not seen in any other part of the tube. In nitrogen this spectrum has often been observed since v. de Willigen first drew attention to it, and was recently mapped by Ångström and Thalèn. It is a channelled-space spectrum, fading away towards the blue. The bands partially overlap some of the bands which are seen in the spectrum of the positive discharge, so that with low dispersive powers it might seem as if in the negative glow some of the ordinary bands were greatly increased in intensity. But in reality a new series of bands is added at the negative pole, as will be seen with a good spectroscope, even if one prism only be used. The ordinary spectrum of the positive discharge no doubt is also present, though weak, in the negative glow, and often traces of the spectrum of the negative pole are seen in the positive discharge; but there can be no doubt that we have to deal with two distinct spectra, although it may not be easy to separate them entirely. When the pressure is much reduced the negative glow gradually extends into the whole tube, and the spectrum is then well seen in the capillary part.

Discussion on the Chemical Origin of the above Spectra.—Some discussion has taken place on the chemical origin of the spectrum seen in the positive discharge. In the year 1872 the writer of the present Report ('Proc. R. Soc.,' xx. p. 482), described some experiments, in which he showed that when sodium is heated in a nitrogen tube the band spectrum disappears, and is replaced by a series of lines which he thought belonged to nitrogen. He drew the conclusion from his experiment that the bands were due to an impurity of an oxide of nitrogen. It has since, however, been shown, especially by Salet, that the disappearance of the bands is due to another cause, and that the line spectrum which appears on heating the sodium is not due to nitrogen. Salet also showed how, with proper precautions, sodium may be heated in a tube containing nitrogen without destroying the band spectrum, and he has therefore furnished the proof that this spectrum is really due to nitrogen, and not to an oxide. Wüllner has also come to the same conclusion. Ångström and Thalèn, however, in their joint paper, support the opinion that the spectrum is that of some oxide of nitrogen. They try to support this view by an experiment showing that when the brush discharge from a Holtz machine is observed in atmospheric air, or when the ordinary discharge of a coil is sent through rarefied air, the band spectrum is seen, and that at the same time the

formation of nitrogen dioxide can be proved by means of a solution of sulphate of iron. But the reasoning proves too much; for oxides of nitrogen are also formed under the influence of the jar discharge when the line spectrum is visible, and we should, therefore, have an equal right to assume that the line spectrum of nitrogen is due to an oxide. It is important to remark that the chemical compounds which are formed outside the spark give us no information on the chemical origin of the spectrum which is given by the spark itself. In the absence of any contradictory proof, Salet's experiment that the band spectrum of nitrogen is seen in a tube in which sodium is heated to its fusing point must be considered conclusive that the spectrum is not due to an oxide.

Compounds of Nitrogen and Hydrogen.

Schuster: 'Brit. Ass.' Brighton (1872) p. 38; 'Nature,' vi. p. 359.
Dibbits, Dr.: 'Spektraal-Analyse,' p. 127; 'Pogg. Ann.' cxxii. p. 518.
Hofmann: 'Pogg. Ann.' cxlvii. p. 95.

The spectrum seen when a weak spark is taken in a current of ammonia is neither that of nitrogen nor that of hydrogen, but must be due to a compound of these two gases. The writer of this report could even obtain a spectrum in a vacuum tube by maintaining a current of the gas through the tube. The spectrum consisted of a single band in the greenish yellow, standing on a faint continuous background. The wave-length was approximately found to be 5686 to 5627 decimètres. If ammonia and hydrogen are burnt together, either in air or in oxygen, a complicated spectrum is obtained, the chemical origin of which has not been satisfactorily explained as yet. Drawings of this spectrum are given by Dibbits and Hofmann.

Compounds of Nitrogen and Oxygen.—No emission spectrum has as yet been found which can be with certainty referred to a compound of nitrogen and oxygen; though it is possible that the above-mentioned spectrum of the flame of ammonia and hydrogen may in part be due to an oxide of nitrogen. The absorption spectrum of the red fumes of nitrogen tetroxide has often been mapped; the most perfect drawing is given by Dr. B. Hasselberg ('Mém. de St. Pét.' xxvi. No. 4). According to Moser ('Pogg. Ann.' clx. p. 177), three bands close to the solar line C disappear when the vapour is heated.

III. *Oxygen.*

Ångström: 'Pogg. Ann.' xciv. p. 141 (1855).
Plücker: 'Pogg. Ann.' cvii. p. 518 (1859).
Huggins: 'Phil. Trans.' cliv. p. 146 (1864).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 23 (1865).
Brassak: 'Abh. Nat. Ges. Halle,' x. (1866).
Wüllner: 'Pogg. Ann.' cxxxv. p. 515 (1868); cxxxvii. p. 350 (1869); cxliv. p. 481 (1872); cxlvii. p. 329; 'Wied. Ann.' viii. p. 253 (1879).
Salet: 'Ann. Ch. Ph.' xxviii. p. 35 (1873).
Schuster: 'Phil. Trans.' clxx. p. 37 (1879); 'Wied. Ann.' vii. p. 670 (1879).

The spectrum of oxygen has been examined by Plücker, Wüllner, Salet, and more recently, by the author of this report, to whose paper the

reader is referred for all historical details, as well as for all measurements. Great care must be taken when experimenting with oxygen to exclude all impurities containing carbon; for the electric spark oxidizing these compounds shows the spectrum of carbonic oxide, which is much more brilliant than the spectrum of oxygen, and may entirely eclipse it. We distinguish four spectra of oxygen.

The Elementary Line-spectrum of Oxygen.—This is the spectrum which appears at the highest temperature to which we can subject oxygen; that is, whenever the jar and air-break are introduced into the electric circuit. It consists of a great number of lines, especially in the more refrangible part of the spectrum. It has been called elementary line-spectrum to distinguish it from the other line-spectrum, because, according to one hypothesis, which has been suggested, to explain the variability of spectra, the molecule which gives this spectrum is in a simpler or more elementary state than that which gives the other or so-called compound line-spectrum. We may, however, adopt the nomenclature independently of any hypothesis which may have suggested it.

The Compound Line-spectrum of Oxygen.—This spectrum appears at lower temperatures than the first. It consists of four lines: one in the red, two in the green, and one in the blue. With the exception of the blue line, all the lines in this spectrum widen very easily, and with an increase of pressure, more easily even than the hydrogen lines. They do not widen out equally on both sides, but more towards the red than towards the violet. This fact is especially noticeable in the more refrangible of the two green lines. The blue line always remains sharp.

The Continuous Spectrum of Oxygen.—This spectrum appears at the lowest temperature at which oxygen is luminous. The wide part of a Plücker tube, filled with pure oxygen, generally shines with a faint yellow light, which gives a continuous spectrum. Even at atmospheric pressure this continuous spectrum can be obtained by putting the contact breaker of the induction coil out of adjustment, so that the spark is weakened. According to Becquerel an excess of oxygen in the oxyhydrogen flame produces a yellow colour, which colour very likely is due to this continuous spectrum of oxygen. The continuous background which often accompanies the elementary line-spectrum must not be confounded with this spectrum.

The Spectrum of the Negative Glow.—This spectrum, which was first accurately described by Wüllner (1872), is always seen in the glow surrounding the negative electrode in oxygen. It consists of five bands: three in the red and two in the green. The least refrangible of the red bands is so weak that it easily escapes observation; the two other red bands are rather near together, and may be taken for one single band if the dispersion applied is small. The two green bands, which appear of the same brightness throughout, with pretty sharply defined edges, are resolved into a series of lines, when looked at with high optical powers. The same no doubt holds of the red bands; only the resolution has not been effected, owing to the weakness of the light.

Transformation of Spectra into each other.—The following description of the appearance of a vacuum-tube filled with pure oxygen, as it undergoes gradual exhaustion, will give an idea of the way in which the spectra of oxygen gradually diffuse into each other:—

'At first the spark has a yellow colour, and the spectrum is perfectly continuous. Almost immediately, however, four lines are seen in the

capillary part above the continuous spectrum. One of these lines is in the red, two are in the green, and one is in the blue. The discharge still passes as a narrow spark throughout the length of the tube. In the wide part the spectrum remains continuous, and it extends more towards the red and blue than in the capillary part. It seems as if the four lines had taken away part of the energy of the continuous spectrum. As the pressure diminishes, these lines increase considerably in strength, the spark spreads out in the wide part of the tube, and the intensity of the continuous spectrum is, therefore, considerably diminished, while it still forms a prominent part in the spectrum of the capillary part. When the pressure is small the continuous spectrum decreases in intensity. At the same time the negative glow, with its own characteristic spectrum, gradually extends through the negative half of the tube into the capillary part. The continuous spectrum has now entirely disappeared; the bands of the negative pole and the four lines stand out on a perfectly black background. It is under these conditions that the change from the compound line-spectrum to the elementary line-spectrum is best studied. The mere insertion of the Leyden jar, I find, makes hardly any difference; the jar does not seem to be charged at all. If, in addition to the jar, we insert a movable air-break, which can be opened or closed at will, while we look through the spectroscope, we shall be able to see alternately two perfectly distinct spectra. If the air-break is closed, the four lines of the compound spectrum only are seen; if the air-break is opened these four lines will disappear entirely, and the elementary line-spectrum will come out. We have here as complete a transformation as we have from the band to the line spectrum of nitrogen, taking place under exactly the same circumstances. We have, therefore, the same right to consider the two-line spectra of oxygen as two distinct spectra as we have in the case of the two spectra of nitrogen.'[1]

Chemical Origin of Spectra.—There can be no doubt that all the above spectra really belong to oxygen. They appear in whatever way the oxygen has been prepared. They are seen with electrodes of aluminium, platinum, silver, brass, and iridium. The glass also could not have introduced any appreciable impurity, for all the spectra were observed in a large glass receiver in which no part of the spark was within two and-a-half inches from the glass.

It has been observed already that great caution is necessary to exclude all carbon impurities, and the reader is warned that several descriptions of the carbonic oxide spectrum as a supposed oxygen spectrum have even recently appeared.[2]

IV. *Carbon.*

Swan: 'Phil. Trans. Ed.' xxi. p. 411 (1857).
Plücker: 'Pogg. Ann.' cv. p. 77 (1858); cvii. p. 533 (1859).
V. d. Willigen: 'Pogg. Ann.' cvii. p. 473 (1859).
Attfield: 'Phil. Trans.' clii. p. 221 (1862); 'Phil. Mag.' xlix. p. 106 (1875).
Dibbits: 'De Spectraal Analyse' (1863); 'Pogg. Ann.' cxxii. p. 497 (1864).
Morren: 'Ann. Chim. Phys.' iv. p. 305 (1865).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 1 (1865).

[1] *Phil. Trans.* clxx. p. 51.
[2] Paalzow, *Wied. Ann.* vii. p. 130.

Huggins: 'Phil. Trans.' clviii. p. 558 (1868).
Lielegg: 'Wien. Ber.' lvii. (2) p. 593 (1868).
Watts: 'Phil. Mag.' xxxviii. p. 249 (1869); xlviii. pp. 369 and 456 (1874); xlix. p. 104 (1875).
Wüllner: 'Pogg. Ann.' cxliv. p. 481 (1872).
Salet: 'Ann. Chim. Phys.' xxviii. p. 60 (1873).
Ångström and Thalèn: 'Nov. Act. Ups.' ix. (1875).
Lockyer: 'Proc. Roy. Soc.' xxvii. p. 308 (1878); xxx. p. 335 (1880).
Liveing and Dewar: 'Proc. Roy. Soc.' xxx. pp. 152, 494 (1880).
Piazzi Smyth: 'Ast. Obs. Ed.' xiii. (R.) p. 58 (1871); 'Phil. Mag.' xlix. p. 24 (1875); viii. p. 107 (1879).

Few spectra have given rise to so much controversy as the spectrum of carbon. We shall give an account of the most important experiments which have been made on the subject.

The Line-spectrum.—This spectrum appears when a very strong spark is sent through carbonic oxide or carbonic acid. It has been observed and described by Watts, Wüllner, Ångström and Thalèn. The best measurements seem to be given by the two Swedish observers. Watts gives many lines which are not found in Ångström and Thalèn's map, but it seems possible that the separation of carbon and oxygen lines has only been imperfectly effected by Watts. All observers seem agreed in ascribing this spectrum to carbon. Though Huggins and Watts were only able to obtain this spectrum from carbonic oxide and carbonic acid, Ångström and Thalèn seem to have seen it also in hydrocarbons when they used a large condenser.

2. *The Band-spectrum* (*Candle-spectrum*).—This is the spectrum which is observed at the base of every candle and gas flame. The controversy on the carbon spectrum chiefly relates to this spectrum, there being a disagreement of opinion whether it is due to the element carbon or to a hydrocarbon. The spectrum which has first been described by Swan consists of a series of bands apparently fading away towards the blue, but in reality easily resolvable into a series of lines. A good idea of the appearance of this spectrum as it appears in spectroscopes of one prism, is obtained from the drawing given in Lecoq de Boisbaudran's Atlas. Ångström and Thalèn and Watts give more detailed drawings and measurements. The spectrum was considered by Swan to be due to a hydrocarbon, but Swan's experiments were only made with gases containing hydrogen. Attfield discussed the question at great length in 1862, and came to the conclusion, that the spectrum was really due to carbon. The experiments which were considered crucial by Attfield and the great majority of observers were as follows:—

1. A flame of cyanogen in oxygen shows, amongst other bands, this spectrum *most brilliantly*, after both gases have been carefully dried. Cyanogen burning in air also gives the spectrum, but more faintly.

2. Sparks taken in the following gases, at atmospheric pressure, carefully prepared and dried, show the spectrum.

Cyanogen.
Carbonic oxide.
Carbon bisulphide.

These gases have only carbon in common, and, unless the experiments are vitiated by impurities, they prove undoubtedly that the spectrum is due to the element carbon.

Mr. Attfield's paper induced Morren to take up the question. Starting with the intention of disproving Attfield's conclusions he ended by being convinced that he was right. Entirely confirming Attfield's experiments Morren satisfied himself that the candle spectrum was really due to carbon, and not to a hydrocarbon. He especially testifies to the brilliancy of the spectrum in a flame of cyanogen and oxygen.

Dibbits had already, before Morren, arrived at the same conclusion. He was the first to furnish an answer to the theoretical objection which can be raised against Attfield's explanation, and which at first sight appears serious. The temperature of an ordinary flame is certainly not high enough to volatilise carbon. How, then, can carbon be present in the state of vapour and give us a discontinuous spectrum. Dibbits explains the difficulty by saying that carbon exists before combustion, combined with hydrogen; after combustion it is combined with oxygen, and it must therefore have existed during a certain stage of transition in the form of simple carbon uncombined. During this stage of transition it gives us the carbon spectrum. He supports the explanation by the fact that a flame of carbonic oxide does not show the spectrum, because in it the carbon is never in a free and uncombined state. Dibbits' view has received a good deal of support by some very interesting experiments made recently by Gouy ('C. R.' lxxxiv. p. 231). In a Bunsen flame, the spectrum under discussion is confined to a narrow cone; Gouy charges the air before it enters the burner with powdered salts in a finely divided state, and shows that at the same place where the candle-spectrum appears we may obtain the spectra of bodies which it would be impossible to volatilise in the flame. Thus the salts of iron, cobalt, manganese, silver, give lines which we know to be due to these metals, as they are found in their spectra obtained by means of electric sparks. Even platinum salts give a spectrum in the blue cone, but it is not certain that this spectrum is really due to platinum in an uncombined state. Gouy believes that these experiments indicate a very high temperature in the blue cone of a Bunsen flame, but we think an explanation, identical with the one given by Dibbits for carbon, will be found more plausible. V. de Willigen had already, before Attfield, made some not quite satisfactory experiments tending to show that the candle-spectrum is due to carbon. Plücker and Hittorf, as well as Wüllner, arrive (after Attfield) at the same conclusion. Watts has made a long series of experiments, all tending to support Attfield's view. In addition to the gases experimented on by Attfield he took carbonic tetrachloride and obtained from it the candle-spectrum. Lockyer has quite recently experimented with the same gas and shown that this much discussed spectrum can be obtained, when a strong spark does not reveal the presence of hydrogen. Huggins' attention was drawn to this spectrum through his observations on comets, and he also obtained the candle-spectrum in a current of cyanogen gas, and therefore considered the spectrum to be due to carbon.

On the whole it may be said that, from the publication of Attfield's paper until the year 1875, every spectroscopist, whether he was a chemist or a physicist, who had set to work to decide the question, came to the conclusion that the candle-spectrum was a true spectrum of carbon, and the question appeared to be settled. In the year 1875, after Ångström's death, Thalèn published a paper in which he describes some experiments jointly made with Ångström. In consequence of these experiments the

authors expressed the opinion that the candle-spectrum was due to a hydrocarbon. The experiments which they gave in support of their view were made by taking the spark of carbon electrodes in various gases and examining the spectra of the 'auréole'[1] or 'glory,' as it might be called. If the spark is taken in oxygen the undoubted spectrum of carbonic oxide appears; in hydrogen the candle-spectrum is seen; and in nitrogen some blue and violet bands are added to the candle-spectrum which appear to be due to a compound of carbon and nitrogen. As it is known that acetylene is formed when the spark is taken in hydrogen, Ångström and Thalèn conclude that the spectrum seen in the 'glory' is due to acetylene.

Recently Professors Liveing and Dewar have supported Ångström's view. The following quotations from their paper will give an idea of the view taken up by the two Cambridge professors:—

'Our faith in the conclusions of Ångström and Thalèn on this subject has been much strengthened by our own observations, which we now proceed to describe' (p. 154).

Their experiments consisted in observing the spectra seen in the electric arc passing between carbon poles in various gases, such as air, carbonic acid, hydrogen, nitrogen, chlorine, carbonic oxide, nitric oxide, and ammonia. They also examined some flames of carbon compounds. The following is their summary of that part of their work which relates to the candle-spectrum:—

'In the next place, the green and blue bands, characteristic of the hydrocarbon flame, are well seen when the arc is taken in hydrogen; but though less strong when the arc is taken in nitrogen or in chlorine, they seem to be always present in the arc whatever the atmosphere. This is what we should expect, if they be due, as Ångström and Thalèn suppose, to acetylene; for we have found that the carbon electrodes always contain, even when they have been long treated in chlorine, a notable quantity of hydrogen.

'In the flames of carbon compounds they by no means always appear; indeed it is only in those of hydrocarbons or their derivatives that they are well seen. Carbonic oxide and carbon disulphide, even when mixed with hydrogen, do not show them; and if seen in the flames of cyanogen, hydrocyanic acid, and carbon tetrachloride mixed with hydrogen, they are faint, and do not form a principal or prominent part of the spectrum. This is all consistent with the supposition of Ångström and Thalèn.'

The experiment, noticed above, on carbon tetrachloride was made by Lockyer in answer to Professors Liveing and Dewar's paper.

To recapitulate shortly the arguments on either side: Those who believe the spectrum to be due to the element carbon rely chiefly on the brilliancy with which these bands are developed when cyanogen is burnt in oxygen, also when the spark is taken in cyanogen, carbon tetrachloride, and carbonic oxide at high pressure; all the gases being dried with the greatest care. Those who oppose this view and who hold that the spectrum is due to a hydrocarbon, refer to the impossibility of excluding all

[1] The French language is the only one which possesses, as far as I know, an appropriate word for the sheet of light connecting under certain conditions the electrodes in addition to the spark proper or *trait de feu*. The term 'glory' was, as far as he can remember, suggested to the writer by the late Prof. Maxwell.

traces of moisture, and to the fact that this spectrum is well developed under circumstances where we know hydrocarbons to be present. Finally we give the wave-lengths of the least refracted lines of the most conspicuous bands. According to Ångström and Thalèn they are: 5633·0; 5164·0; 4736·0. Watts gives slightly different values, viz.: 5634·7; 5165·5; 4739·8.

Compounds of Carbon and Nitrogen.—The flame of cyanogen, which had already been examined by Faraday and Draper, before the days of Spectrum Analysis, shows a series of bands in the red, reaching into the green, which are not seen in any other flame. Plücker and Dibbits have given drawings of these bands, which have their sharp edge on the most refrangible side. There is no doubt that they are due to a compound of carbon and nitrogen. The same bands are also seen, when cyanogen is burnt in oxygen, although, according to Morren and Watts, they are less developed, a fact which they ascribe to the smaller quantity of undecomposed cyanogen at the higher temperature of the flame in oxygen. According to Plücker and Hittorf, and also Dibbits, the bands in the red become more brilliant when cyanogen is burnt in oxygen. There seems to be a conflict between the increased brilliancy due to a higher temperature and the decrease of luminosity due to the more rapid decomposition in the oxygen flame.

Besides the red and yellow bands, a cyanogen flame shows a series of bands in the blue, violet, and ultra-violet. These bands have been, until quite recently, ascribed to carbon, as they have also been observed in carbon compounds not containing nitrogen, but according to the experiments of Professors Liveing and Dewar, they can in those cases always be traced to impurities containing nitrogen.

Thus, according to Watts, the bands are seen when a spark is taken in carbonic oxide at the atmospheric pressure. According to Professors Liveing and Dewar this is true, if the carbonic oxide has been prepared from ferrocyanide of potassium. When the gas, however, was made by the action of sulphuric acid on dried formiate of sodium, a faint trace of one of the bands only could be detected. When the gas was prepared by heating a mixture of quicklime with pure and dry potassium oxalate, no trace whatever of the bands in question appeared.

Similarly Watts and Lockyer had observed the bands in a tube containing carbon tetrachloride, but, according to Professors Liveing and Dewar, these bands do not appear when the tetrachloride has been well purified, and when all traces of air have been expelled from the tube.

Experiments with naphthalene gave the same results; the bands did not appear when the air had been properly expelled from the tube.

These experiments seem conclusive as to the chemical origin of the spectrum in question. It seems remarkable, however, that this spectrum should be reversed in the solar spectrum; for a photograph taken by Lockyer shows a decided coincidence of one of the flutings with a series of dark lines in the solar spectrum; and Professors Liveing and Dewar consider the reversal of another set of flutings still further in the ultra-violet as probable. The spectrum we have been discussing consists chiefly of three sets of bands; the first set consists of seven fluted bands (wave-lengths 4600 to 4502, Watts), the second set of six bands ($\lambda = 4220$ to 4158, Watts), and the third set in the ultra-violet of five bands ($\lambda = 3883{\cdot}5$ to 3850, Liveing and Dewar). According to Professors Liveing and

Dewar there is another band still further in the ultra-violet, and apparently coinciding with the solar line P.

Spectrum of Carbonic Oxide.—It has been said already that great care must be taken, in order to produce a spectrum of oxygen, to exclude all carbon impurities. If this precaution is not taken a spectrum is obtained which no doubt belongs to carbonic oxide. The spectrum is most brilliantly obtained in a Plücker's tube filled with carbonic oxide. The spectrum was carefully examined by Wüllner, and was measured by Watts as well as Ångström and Thalèn. As some of the bands are situated rather near to the bands of the candle-spectrum, the two spectra have often been confounded, and we therefore give the wave-lengths obtained by the Swedish observers for the most conspicuous bands: 5607·5; 5197·0; 4833·5.

Spectrum of Carbonic Acid.—Plücker mentions already in his first paper on the spectra of gases (1858) that carbonic acid in a vacuum-tube shows a band in the red which is very strong at first and gradually disappears. This band he attributes to carbonic acid (1859), which, it is known, is gradually decomposed by the spark. Wüllner has carefully examined and described the changes going on in the spectrum seen in a vacuum-tube when it is first filled with carbonic acid.

Professor Piazzi Smyth ('Phil. Mag.' xlix. p. 24) has given some very careful and valuable measurements of the details in some of the flutings of the spectra which we have described. He ascribes the candle spectrum to a hydrocarbon, and the spectrum which we have put down as belonging to carbonic oxide, he refers to carbon, as it is also visible in tubes not containing any oxygen. Professor Piazzi Smyth has, however, not filled his own tubes, and we must be careful not to attach too much value to the labels put on vacuum tubes by the glass-blower who has filled them. According to Watts, a tube containing hydrocarbons does not show this spectrum when the gas is heated in contact with metallic sodium.[1]

V. *Chlorine.*

V. d. Willigen: 'Pogg. Ann.' cvi. p. 624 (1859).
Plücker: 'Pogg. Ann.' cvii. p. 528 (1859).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 24 (1865).
Salet: 'Ann. Chim. Phys.' xxviii. p. 24 (1873).
Ciamician: 'Wien. Ber.' lxxviii. (II.) p. 872 (1878).
Morren: 'C. R.' lxviii. p. 376 (1869).
Gernez: 'C. R.' lxxiv. p. 660 (1872).
W. A. Miller: 'Phil. Mag.' xxvii. p. 81 (1845).

The Line-spectrum.—This is the spectrum which is obtained if an electric spark is taken in chlorine gas. It has been mapped by Plücker and Hittorf, whose measurements have been reduced to wave-lengths by Watts. Some earlier measurements of the strongest lines will be found in Plücker's paper. Salet has also mapped this chlorine spectrum as well as could be done with a spectroscope of small dispersive powers. A few of the lines have been measured by Ångström ('Phil. Mag.' xlii. p. 398). None of these measurements lay claim to great accuracy. Recently Ciamician has given a detailed account of the successive changes which this spectrum undergoes, if the pressure is either greatly reduced or

[1] *Phil. Mag.* xlviii. p. 456 1874).

increased. Lines, which are visible at one pressure, altogether disappear at another. Some preliminary experiments have convinced the writer of this report, that we have here to deal with a mixture of several overlapping spectra. In reality the phenomena are even more complicated than Ciamician supposes, but a more extensive series of experiments is required before any detailed account can be given.

The Band-spectrum.—This is the spectrum which is obtained by absorption, if sunlight is sent through a long column of chlorine gas. The spectrum was first observed by Morren, who describes it, but does not give any measurements. It has never been obtained as an emission spectrum.

Compounds of Chlorine and Oxygen.—The absorption spectra of chlorine trioxide and chlorine peroxide were examined by Prof. W. A. Miller in 1845 and found to be identical, while chlorine monoxide did not show any bands. As no other case is known in which two different compounds give the same spectrum, and as the oxides of chlorine are very unstable, there is no doubt that the spectrum of one of them only was observed, that gas to which the spectrum belongs being also present when the other oxide was examined. Gernez confirming Miller's results, also found that a weak solution of these gases in some liquids presents the same absorption bands. According to Gernez a long tube filled with chlorine monoxide shows the same spectrum. A drawing of the spectrum will be found in Miller's paper.

VI. *Bromine.*

Plücker: 'Pogg. Ann.' cvii. p. 527 (1859).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 24 (1865).
Salet: 'Ann. Chim. Phys.' xxviii. p. 26 (1873).
W. H. Miller: 'Phil. Mag.' ii. p. 381 (1833).
W. A. Miller: 'Phil. Mag.' xxvii. p. 86 (1845).
Roscoe and Thorpe: 'Phil. Trans.' clxvii. p. 207 (1876).
Moser: 'Pogg. Ann.' clx. p. 177 (1877).
Ciamician: 'Wien. Ber.' lxxviii. (II.) p. 874 (1878).
Hasselberg: 'Mém. de St. Pét.' xxvi. 4 (1878).

The Line-spectrum.—We only possess approximate measurements of this spectrum by the same authors who mapped the chlorine spectrum. The spectrum appears whenever the electric discharge passes through the vapour of bromine. Ciamician has observed similar changes in the spectrum of bromine to those already mentioned in chlorine.

The Band-spectrum.—This spectrum is obtained by absorption. It was first observed by Prof. W. H. Miller in 1833.

Drawings and measurements have been made by Roscoe and Thorpe and Moser, who mentions some changes which the spectrum shows on being heated. The most detailed and apparently the best drawings are given by Dr. B. Hasselberg. Both Moser and Hasselberg's measurements begin in the orange, so that for absorption-bands in the red we have to refer to Roscoe and Thorpe's map.

A flame of hydrogen containing bromine gives a continuous spectrum only. Similarly, if a hard glass tube is heated to a low red heat and bromine introduced, the gas becomes luminous; but a continuous spectrum only is seen. It is uncertain whether this continuous spectrum is due only to the bands of the absorption spectrum widened by an increase of temperature, or whether we have to deal with a true continuous spectrum.

In the latter case we should have the remarkable fact of a vapour giving a continuous spectrum at a higher temperature than the one at which it gives the band spectrum.

VII. *Iodine.*

Plücker: ‘Pogg. Ann.’ cvii. p. 638 (1859).
Wüllner: ‘Pogg. Ann.’ cxx. p. 158 (1863).
Mitcherlich: ‘Pogg. Ann.’ cxxi. p. 474 (1864).
Plücker & Hittorf: ‘Phil. Trans.’ clv. p. 24 (1865).
Salet: ‘C. R.’ lxxiv. p. 1249; ‘Ann. Chim. Phys.’ xxviii. p. 29 (1872).
W. H. Miller: ‘Phil. Mag.’ ii. p. 381 (1833).
W. A. Miller: ‘Phil. Mag.’ xxvii. p. 86 (1845).
Thalèn: ‘Stockholm Akad. Handl.’ viii. (1870).
Lockyer: ‘Proc. Roy. Soc.’ xxii. p. 377 (1874).
Lockyer and Roberts: ‘Proc. Roy. Soc.’ xxiii. p. 348 (1875).
Ciamician: ‘Wien. Ber.’ lxxviii. (II.) p. 877 (1878).

The Line-spectrum.—This spectrum, which appears under the same circumstances as the line-spectra of chlorine and bromine, has been mapped by the same observers. Ciamician found in this spectrum similar changes as when the pressure was greatly reduced.

The Band-spectrum.—This spectrum, which is easily obtained as an absorption-spectrum at low temperatures, was first observed by Prof. W. H. Miller, 1833. It has been carefully mapped by Thalèn. The darkening and widening of the bands when the temperature is increased has been described by Thalèn and Lockyer. It is a curious fact that the absorption on heating extends continuously into the blue and violet (which are clear at low temperature) so that the whole of the more refrangible end of the spectrum can be blocked out. At higher temperatures, however, the violet and blue light is transmitted, and the spectrum resembles again that of low temperature. Thus Lockyer heating various vapours in an iron tube placed inside a furnace, supplied with coke or charcoal, found that iodine gave an intense bank of general absorption in the violet, where at the ordinary temperature the vapour transmits light. In his joint experiments with Mr. Chandler Roberts, in which the vapours were heated to a still higher degree he found that the violet and blue light was transmitted again.

Salet could obtain this spectrum as an emission spectrum in the wide part of a Geissler tube. Also by heating the vapour of iodine round a white-hot platinum spiral.

Wüllner, however, was the first to observe this spectrum as an emission spectrum by charging a hydrogen flame with iodine vapour.

Ångström had already examined the spectrum of an alcohol flame containing iodine, but had obtained a different spectrum, showing bands in the green. According to Mitcherlich the latter spectrum is obtained if a flame of hydrogen contains small quantities of iodine. If large quantities are present the reversal of the absorption spectrum is seen. Salet did not observe this spectrum; but the one mentioned by Ångström and Mitcherlich, which very likely is that of some compound of iodine.

Spectrum of Iodine Chloride.—The absorption spectrum of the vapour of iodine chloride was observed by Gernez (‘C. R.’ lxxiv. p. 660) and mapped by Roscoe and Thorpe, who drew attention to the resemblance of this spectrum to that of bromine. (‘Phil. Trans.’ clxvii. p. 207.)

The vapour of *protobromide of iodine* also gives an absorption spectrum similar to the above (Gernez: 'C. R.' lxxiv. p. 1190—1874).

VIII. *Fluorine.*

Séguin: 'C. R.' liv. p. 933 (1862).
Salet: 'Ann. Chim. Phys.' xxviii. p. 34 (1873).

A spark taken in fluoride of silicium shows a few lines, which are not seen when the spark is taken in chloride of silicium. These lines Salet attributes to the element fluorine; they are all situated in the red. Séguin observed a strong blue ray common to fluoride of silicium and fluoride of boron, and attributes it to fluorine. Séguin does not say in what way the gases were prepared, but it seems possible that the blue line is the calcium line, which very often appears when calcium compounds are used in preparing gases.

IX. *Sulphur.*

Séguin: 'C. R.' liii. p. 1272 (1861).
Mulder: 'Jour. f. Prakt. Chem.' xci. p. 112 (1864).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 13 (1865).
Salet: 'Ann. Chim. Phys.' xxviii. p. 37 (1873).
Lockyer: 'Proc. Roy. Soc.' xxii. p. 374 (1875).
Gernez: 'C. R.' lxxiv. p. 803 (1872).

The Line-spectrum.—If sulphur is heated to its point of ebullition in a vacuum-tube, and the jar discharge passed through the vapour, we obtain a line-spectrum, which was first measured by Plücker and Hittorf (Watts, Index of Spectra). Salet also has mapped this spectrum, and a few of the lines have been measured by Ångström ('Phil. Mag.' xlii. p. 397). Séguin has obtained this spectrum by heating sulphur in hydrogen and passing a spark at atmospheric pressure through the hydrogen. He was thus the first to observe this spectrum.

The Band-spectrum.—If the ordinary discharge is passed through a vacuum-tube, in which sulphur is kept boiling, a beautiful band-spectrum is obtained. Plücker and Hittorf give a coloured drawing of this spectrum, but without measurements. Measurements have been supplied by Salet, who furnishes us with the best investigation on sulphur spectra which we at present possess. He was the first to observe this spectrum as an absorption spectrum, by passing the light through sulphur vapour heated to a high temperature, an observation which has been confirmed by Gernez and Lockyer.

The flame of sulphur, as well as the flame of sulphuretted hydrogen, gives a continuous spectrum only, but if a hydrogen flame contains traces of sulphur a band-spectrum is seen. This spectrum was first obtained by Mulder by heating sulphur near the orifice of a glass tube through which hydrogen passed, the hydrogen being burnt at the orifice. Salet increased the luminosity of the flame by pressing it against a layer of cold water falling vertically. According to him the band-spectrum thus obtained is the same as the one seen in a vacuum-tube; the relative intensity of some of the bands only being altered. Considering, however, the small dispersion used by Salet and the large differences between the two spectra shown in his map, it seems probable that we have to deal, in part, at any rate, with a new spectrum, most likely that of a compound.

Some of the bands of the electric spectrum no doubt may be present as well.

The Continuous Spectrum of Sulphur.—Sulphur vapour at comparatively low temperatures shows a continuous spectrum by absorption. The change of this continuous spectrum to the band-spectrum seems to be connected with and dependent on the change in density which sulphur vapour undergoes between the temperatures of 500° and 1000°. Gernez at least mentions that the change takes place simultaneously with a rapid decrease in density.

X. *Selenium.*

Mulder: 'Journ. f. Prakt. Chemie,' xci. p. 113 (1864).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 5 (1865).
Salet: 'Ann. Chim. Phys.' xxviii. p. 47 (1873).
Gernez: 'C. R.' lxxiv. p. 803 and p. 1190 (1874).
Lockyer and Roberts: 'Proc. Roy. Soc.' xxiii. p. 348 (1875).

The spectra of selenium are analogous to those of sulphur, and are obtained in the same way. According to Salet the band-spectrum may be obtained in the flame of burning selenium, or when the metalloid is heated in a hydrogen flame (Mulder). Sulphur, as we have observed, gives under the same conditions a continuous spectrum only. The band-spectrum of selenium has been obtained by absorption in selenium vapour by Gernez. At 700°, according to this observer, the vapour of selenium absorbs all the light with the exception of the red; but if the temperature is raised the tint of the vapour brightens, and the different regions of the spectrum re-appear, furrowed with groups of black bands in the blue and violet. The band-spectrum has also been obtained by Lockyer as an absorption spectrum.

Gernez also describes the absorption spectra shown by the vapours of selenious acid, protochloride of selenium, and bromide of selenium; but he does not give any measurements.

XI. *Tellurium.*

Thalèn: 'Nov. Act. Ups.' (111) vi. (1868).
Salet: 'Ann. Chim. Phys.' xxviii. p. 49 (1872).
Gernez: 'C. R.' lxxiv. p. 1190 (1872).

The *line-spectrum* of *tellurium* can be obtained, like that of metals, by taking the jar discharge from tellurium poles in air. It has been measured by Thalèn. Salet has observed a band-spectrum in vacuum-tubes in which tellurium was heated, but he could not decide whether this spectrum did not rather belong to an oxide. Gernez heated tellurium in an atmosphere of carbonic acid gas to a temperature near that at which glass begins to melt, and he observed in the transmitted light an absorption spectrum, extending from the yellow into the violet.

Protochloride of tellurium, according to the same observer, gives a band-absorption spectrum, chiefly in the orange and green. The vapour of *protobromide of tellurium* absorbs the light in the red and yellow.

XII. *Phosphorus.*

Séguin: 'C. R.' liii. p. 1272 (1861).
Plücker and Hittorf: 'Phil. Trans.' clv. p. 24 (1865).
Salet: 'Ann. Chim. Phys.' xxviii. p. 56 (1873).

Christofle and Beilstein: 'C. R.' lvi. p. 399 (1863).
Mulder: 'Journ. f. Prakt. Chemie,' xci. p. 111 (1864).
Lecoq de Boisbaudran: 'Spectres Lumineux' (1874).
Lockyer: 'Proc Roy. Soc.' xxii. p. 374 (1874).

By passing a spark in hydrogen at atmospheric pressure in which phosphorus was heated, Séguin observed a line-spectrum. Plücker and Hittorf and Salet observed the same spectrum by treating phosphorus in a vacuum-tube like selenium. The spectrum consists of comparatively few lines, which are chiefly situated in the orange and green.

A hydrogen flame containing traces of phosphorus takes a green colour, and shows a spectrum which was first drawn by Christofle and Beilstein. Mulder makes the interesting remark that a drop of ether in the hydrogen apparatus altogether prevents the formation of this spectrum. He tries to explain the fact by assuming that the ether prevents the oxidation of the phosphorus.

Salet rendered the green flame more luminous by cooling it. The most successful way of effecting this seems to be to surround the tube, through which the hydrogen escapes, by a wider tube, and to blow cold air through this wider tube. This cooling produces a change in the relative intensity of the bands, the red and yellow bands being strengthened. Lecoq de Boisbaudran gives a careful drawing of this spectrum; which very likely is due to some compound of phosphorus.

XIII. *Silicon.*

Troost et Hautefeuille: 'C. R.' lxxiii. p. 620 (1871).
Salet: 'Ann. Chim. Phys.' xxviii. p. 65 (1873).
Plücker: 'Pogg. Ann.' cvii. p. 531 (1859).

A spectrum of silicon may be obtained by taking the jar discharge between poles of silicon. Kirchhoff has thus mapped two bands, one of which, however, according to Salet, is due to lead. Troost and Hautefeuille mention that they have obtained in this way a great number of lines, but their measurements are all given to an arbitrary scale. By passing a spark through the chloride and fluoride of silicon we can eliminate the lines due to the halogens, and obtain a spectrum of lines which must be due to silicon. This has been done by Salet. Salet has also obtained spectra of the hydrogen flame charged with chloride, bromide, and iodide of silicon. Most of the bands observed are common to all three compounds, but whether they are due to silicon or to a compound with oxygen or hydrogen is uncertain. Plücker observed in a vacuum-tube filled with chloride of silicon a band-spectrum, which very likely is due to that compound. Silicon fluoride also gives a band-spectrum under the same conditions. Bromide of silicon, according to Salet, gives a continuous spectrum in a vacuum-tube, when a weak spark is passed through it. A strong spark decomposes the gas, and the lines of bromine and silicon appear.

XIV. *Boron.*

Troost et Hautefeuille: 'C. R.' lxxiii. p. 620 (1871).

The spectrum of boron was obtained by Messrs. Troost et Hautefeuille by comparing together the spectra obtained between platinum poles in atmospheres of fluoride of boron and fluoride of silicon. It consists of several groups of brilliant double lines in the yellow, green, and blue.

§ 2. On the Influence of Temperature and Pressure on the Spectra of Gases. *By* Dr. Schuster, *F.R.S.*

A study of the changes which may be observed in the spectra of gases, under varying circumstances, is of great importance, both from a practical and a theoretical point of view. We are here chiefly concerned with the practical side; and it is clear that a full investigation of all spectroscopic variations attending changes of physical conditions, will ultimately lead to a science which will aim, not only at a merely qualitative analysis, as the original spectroscopy did, but which will enable us to determine the exact physical state of a luminous body, at whatever distance from us that body might be placed.

There is some difficulty in arranging the great quantity of partially unconnected facts which we shall have to place before the reader. We shall endeavour, for clearness' sake, to arrange our material under five different heads. We shall first discuss what changes we have a right to expect in the appearance of a spectrum, if the quantity of luminous matter is increased, or if the temperature is raised, the absorbing properties of the gas remaining unaltered. We shall next speak of the widening of lines, which, as we shall see, often accompanies an increase of pressure. Then we shall treat of the different spectra given by one and the same body at different temperatures, and we shall see how far satisfactory explanations have been offered for their existence.

So far our road will be clear, but we shall find that these spectra of different orders, as they have been called, are only extreme cases of continuous changes which are nearly always going on. Very often we can refer these continuous changes to a gradual displacement of one spectrum by another; but often we shall not be able to prove the existence of a second spectrum. There is, *à priori*, nothing impossible, or even improbable, in the view that the relative intensity of different lines may be different at different temperatures, and often when we observe a variation, we may equally well explain it by assuming the gradual appearance of a new spectrum, or an alteration only in the relative intensities of the lines. It becomes then a matter of extreme difficulty to decide which of the two suppositions is correct. In doubtful cases we may often be able to obtain important information by means of a method which is little understood, even by spectroscopists. It is the method which has first been extensively used and investigated by Mr. Lockyer, of projecting an image of the luminous source, spark, arc, or flame on the slit of the spectroscope, and thus localising the spectra which are thrown and confused together, if the luminous source is examined directly without the interposition of a lens. We shall see how, by means of this method, we shall often at a single glance be able to tell how the body will behave at different temperatures and under different pressures. Many facts which have been quoted as remarkable might have been foretold by means of this method. Our fourth chapter will be devoted to it. In our last chapter we shall have to give an account of some changes which have not found a place under the previous heads.

I. *Influence of Thickness of Radiating Layer on the Spectra of Gases.*

Let a be the coefficient of absorption for a certain wave-length of a layer of gas, of thickness and density equal to unity. Let e be the

radiation of a perfectly black body for the given wave-length, and at the temperature of the body, the radiation of which we are considering. Then the radiation E of a layer of thickness a and density δ will be[1]—

$$E = \left[1 - (1 - \alpha)^{a\delta}\right] e$$

We pass over some obvious consequences of this formula, which have been treated in detail in Zöllner's paper, but shall discuss whether a mere increase in the thickness or density of the layer can alter the relative intensities of the lines. Put $d\delta = \sigma$ and let E_1 be the radiation of the same body for another wave-length, e_1 being the corresponding radiation for a perfectly black body.

In the first place we remark that there can only be one finite value of σ, for which the two radiations can be equal; for the equation

$$\left[1-(1-\alpha)^{\sigma}\right] e = \left[1-(1-\alpha_1)^{\sigma}\right] e_1$$

has only two roots, one of them being $\sigma = o_1$, which case, of course, is excluded from our consideration. For an infinite thickness—

$$\frac{E_1}{E} = \frac{e_1}{e}.$$

Let e_1 be larger than e; then, if for any given value of σ, say σ^1, E_1 is larger than E, it must be also larger for all greater values of σ, for if for any value larger than σ^1, E_1 could be smaller, it would have to be equal to E for two values lying between $\sigma = \sigma^1$ and $\sigma = \infty$; which, as we have seen, is impossible. On the other hand, if, for any value of σ, E_1 is smaller than E, the relative intensities must be reversed by an increase of thickness, for an infinite value of σ will make $E_1 > E$.

We have been assuming that e_1 is larger than e; e being the radiation of a perfectly black body. Now for all temperatures which we are considering, the radiation of a perfectly black body decreases in the visible part of the spectrum with the wave-length. Hence the wave-length, for which E_1 is the radiation, must be larger than the corresponding wave-length for E. Putting all these considerations together we arrive at the following laws:—

1. *If the less refrangible of two rays is the stronger for any given quantity of luminous matter, no increase of that quantity can reverse the relative intensities, but a decrease may render the more refrangible ray stronger.*

2. *If the more refrangible of two rays is the stronger, a sufficient increase in the quantity of luminous matter will, in all cases, reverse the relative intensities, but a decrease will never make the less refrangible ray stronger.*

Zöllner, who was the first to draw attention to the fact that a reversal of relative intensity may be produced by an increase in the quantity of luminous matter, has failed to notice that this inversion can only take place if the less refrangible ray is the weaker of the two.

When we come to look round for examples in which the effect of thickness of a layer can be clearly traced, we shall have difficulty in finding any. For most gases the values of α are exceedingly small, and then, of course, the increase of quantity must be exaggerated to an enormous extent before any appreciable effect is produced. Even on the

[1] Zöllner: *Phil. Mag.* xli. p. 190 (1871); Wüllner: *Wied. Ann.* viii. p. 590 (1879).

sun, the relative intensities of the lines is often the same as that we observe in our laboratory experiments, and where it is not, it does not show such changes as would be produced by a mere increase of the absorbing layer. In liquids, of course, and some vapours which have large absorbing powers, an effect of the thickness of the absorbing layer can be traced.

If the temperature of a radiating gas is increased, the absorbing power for each ray remaining the same, the radiation will vary in the same proportion as e; that is, as the radiation from a perfectly black body. It follows that the more refrangible rays will relatively gain more than the less refrangible rays, but it must be borne in mind that the absolute intensity of any given line can never decrease, unless the quantity of luminous matter decreases.

II. *Widening of Lines.*

In his celebrated paper, 'Optiska Undersökningar'[1] (1853,) Ångström gives two drawings of the hydrogen spectrum. In neither of them are the lines sharp; but in one of them especially they are drawn out into broad bands. The property of widening their lines under certain circumstances has since been found to be common to all bodies, though some of them possess it to a much larger extent than others. Hydrogen and sodium are the best known instances of elements which widen their lines considerably, though in one of the spectra of oxygen, the lines broaden even more easily. Wüllner[2] has given a detailed description of the behaviour of the hydrogen lines under different pressures, both with the condensed and uncondensed discharge. The same author has also given us information as to the widening of some of the oxygen lines in the same paper, and his observations were confirmed and extended by the author of this report.[3] Ciamician[4] has described the widening of the lines of mercury, sodium, and some other gases. The papers of Lockyer, and of Liveing and Dewar will also be found to contain many observations on the widening of lines. We shall refer presently to some of their most important experiments on the subject.

It is a fact which is often, though by no means generally, true, that if a spectrum widens its lines easily, the widening begins with the most refrangible lines. This was first noticed by Plücker and Hittorf in the case of hydrogen. They express themselves as follows:[5]

'Hydrogen shows in the most striking way the expansion of its spectral lines and their gradual transformation into a continuous spectrum. By increasing the power of the coil, Hγ (coincident with solar line near G) first expands, then Hβ (solar F). Let the aperture of the slit be so regulated that the double sodium line will separate into two lines, nearly touching; then the angular breadth of Hβ becoming two or three minutes,[6] the breadth of Hγ is about double. Hα remains almost unchanged after Hγ has passed into an undetermined hazy band, and Hβ extended its decreasing light on its two sides.' A fourth hydrogen line, more refrangible than the others, was discovered by Ångström, and as Goldstein[7] has remarked, this line is the first to widen, thus following

[1] Translated, *Pogg. Ann.* xciv. p. 141 (1855).
[2] *Pogg. Ann.* cxxxvii. p. 339 (1869).
[3] *Phil. Trans.* clxx. p. 37 (1879).
[4] *Wien. Ber.* (2) lxxviii. p. 867 (1878).
[5] *Phil. Trans.* clv. p. 21 (1865).
[6] The large Steinheil spectroscope was used.
[7] *Berl. Ber.* p. 593 (1874).

the general rule. It would be interesting to determine the behaviour of the ultra-violet lines of hydrogen which have recently been discovered.

In the case of oxygen, Plücker and Hittorf have remarked that the less refrangible lines widen most easily. But Plücker and Hittorf did not separate the two line-spectra of oxygen. (*See* Report on Spectra of Metalloids.) The lines belonging to the lower temperature widen more easily perhaps than any other lines, with the exception of the blue line, which always remains sharp, and presents a striking contrast to the other lines. The two green lines belonging to this spectrum widen more easily than the red line; so that the lines which do expand follow the rule. The lines of the other line spectrum do not expand very much, though their edges lose their sharpness at high pressures. Plücker and Hittorf remark that the blue group widens more easily than the violet groups.

The more refrangible of the two double sodium lines (D_2) widens more than the less refrangible component. According to Ciamician's experiments, mercury follows the rule, and widens the most refrangible lines most easily. It has often been remarked that all lines lose the sharpness of their edges when the pressure is increased,[1] but there is a great difference between the cases we have just mentioned and the lines, for instance, of chlorine, bromine, and iodine, or nitrogen, which may become fuzzy, but never spread over an appreciable part of the spectrum. Though the difference is one of degree only, it is very marked. We may say that, as a general rule, if a system of lines widens much or easily, the more refrangible lines of the system will be the first to widen, while if a system of lines shows the broadening to a small degree only, no general rule can be given.

When a line widens, it may do so either symmetrically on both sides, or the widening may be greater on one side. It is a remarkable fact that when a line widens chiefly towards one side, that side is in nearly all, if not in all cases, the less refrangible one.

In the case of the hydrogen lines, it is of some importance to determine whether they widen symmetrically, because the small displacements of the line in stars which are referred to star motions, may be in part due to a one-sided widening. The Greenwich observers[2] have, therefore, made a very careful series of measurements, in order to find out whether the centre of the F line shifts as it broadens. No shift was detected in a range of pressure from 3·0 mm. to 500 mm., the width of the line altering considerably within that range. J. J. Müller's experiments, giving an apparently different result, will be presently referred to.

The lines of sodium seem also to widen nearly equally on both sides. Zöllner[3] has examined these lines with his reversion-spectroscope—an instrument which is pre-eminently fitted for such an investigation. He gives the results in the following words: 'In the more refrangible line, which, with increase of the vapour-density, was the most widened, no displacement was perceptible; meanwhile there appeared to take place in the other line, as the brightness increased, an extremely slight *displacement in the direction of a diminution of the refrangibility.*'

But Zöllner does not seem himself to attach very much value to this observation, the displacement being very slight. Dr. J. J. Müller[4] has

[1] *e.g.* Cailletet, *C. R.* lxxiv. p. 1282 (1872).

[2] *Results of the Astronomical Observations made at the Royal Observatory, Greenwich*, 1876, p. 118.

[3] *Phil. Mag.* xli. p. 204 (1871).

[4] *Leipz. Ber.* (1871) and *Pogg. Ann.* cl. p. 311 (1873).

had the curious idea of examining whether the rate of propagation of a ray of light in space depended on the amplitude of vibration. The wave-length was measured by means of interference fringes of long difference of path (Newton's rings), and he was incidentally led to inquire into the possibility of a displacement of the centre of the sodium lines, when larger quantities of sodium were introduced into a Bunsen flame; in which case it is known the lines are seen to widen. Müller found such a displacement in the same direction as Zöllner, who refers to his experiments as corroborating his own results. But Müller also found the effect he was looking for; that is to say, he found the centre of lines to shift when the light was weakened after it had left the flame. Now this latter part of the investigation has been subjected to a very careful examination by Lippich,[1] who could discover no such effect. As there undoubtedly was a source of error in Müller's experiments, which has not yet been pointed out, we must defer our judgment also on his other results. When he therefore finds a very slight shifting of the hydrogen lines, due to an alteration of the power of the spark, we cannot put his observations on an equal level with the subsequent negative results of the Greenwich observers.

Speaking of reversals in the voltaic arc, Mr. Lockyer[2] adds the following note: 'The absorption-line does not always occupy the exact centre of the bright band. This point is occupying my attention, as it raises a very interesting question connected with molecular vibrations.' In the plates accompanying the paper we find one at least of the aluminium lines between H and K slightly more expanded on the less refrangible side.

Mr. Lockyer[3] has referred to the same question in a recent paper, and mentions two examples in the silver spectrum. In one case (4210·0) the line seemed to be much more widened on the more refrangible side of the absorption line; in the other case (4054·3), it was more widened in the opposite direction. The rubidium line (4202) is also given as more expanded on the less refrangible side.

Profs. Liveing and Dewar[4] mention that the magnesium lines (4703) (4354) widen more on the less refrangible side.

The lines of the lower temperature spectrum of oxygen widen considerably on the less refrangible side. This is very marked in the case of the more refrangible of the two green lines, and of the red line. The centre of the former line shifts through 2Xth mètres.[5] The less refrangible of the two green lines widens more symmetrically. According to Ciamician,[6] most of the mercury lines show this one-sided widening, and with some of them it is so marked that they seem exclusively expanded towards one side only.

I have only come across two cases in which lines seemed to be more widened on the most refrangible side, and neither of them seems to be established beyond doubt. The first is the one in the spectrum of silver mentioned by Lockyer and quoted above. But Profs. Liveing and Dewar did not notice the reversal of the line in question, the wave-length of which they give as 4208. A new line, however, came out at 4211·3; that is on the less refrangible side. It is possible that the dark space between the two

[1] *Wien. Ber.* (2) lxxii. p. 355 (1875).
[2] *Phil. Trans.* clxiv. p. 805 (1874).
[3] *Proc. Roy. Soc.* xxviii. p. 428 (1879).
[4] *Proc. Roy. Soc.* xxviii. p. 367 (1879).
[5] *Wien. Ber.* (2) lxxviii. p. 886 (1878).
[6] *Nature*, xvii. p. 148 (1877).

lines was taken by Lockyer for a reversal, and that consequently the greater intensity and width of the more refrangible line appeared as a one-sided development of the wings. The second case is not very clearly described by Ciamician. In the text of the paper he only mentions that when the double yellow mercury line becomes fuzzy, continuous light is seen to the right and left of it. In the drawing this is figured as a widening of the more refrangible line towards the violet, and of the less refrangible line towards the red. The description is too vague to allow any certain inference to be drawn, but it seems possible, as a simple optical fact, that, when a double line widens, the wings can be traced to a greater distance on that side of each component which is removed from the other.

We have now to discuss the causes which may produce the widening of lines. In the first place it might be suggested that, in accordance with a formula which we have already given, an increase of the quantity of luminous matter would produce an apparent widening of the lines; for it follows from the formula that, unless the coefficient of absorption is absolutely zero for any given wave-length, the spectrum sent out by an infinite number of molecules in the line of sight is always continuous. A greater number of molecules will, therefore, cause the spectrum to approach the continuous state, and the widening of the lines may be due to the first stage towards this approach. To this we shall reply, that an increase in the number of molecules cannot be the primary cause of the widening of lines; for the lines of sodium, for instance, in the sun are comparatively sharp, though the thickness of the absorbing layer is greater than anything we can produce in our experiments. We can prove the same point more clearly in the case of hydrogen. If we enclose the gas in a tube of the form adopted by Mr. Monkhoven and Prof. Piazzi Smyth, so that we may look longitudinally through the capillary bore, we increase the thickness of the radiating layer to a very great extent; yet lines which are sharp when the tube is looked at transversely, will remain sharp when it is looked through longitudinally, although an increase in the pressure or in the intensity of the discharge will at once produce a widening. It must be remembered that the effect of an increased number of radiating molecules will only depend on the curve of intensity near the line. If a line is absolutely sharp, no increase in the number of molecules will ever increase its width, and two lines of the same brightness, which present the same appearance at their edges, must behave exactly in the same way, when the thickness of the radiating layer is increased. Yet, while we have some lines which widen easily and enormously, others, which present the same appearance, do not show any widening. That, if a line is once widened, an increase in the number of radiating or absorbing molecules will increase the apparent extent of the widening is possible, but we must distinguish this effect from the original cause which has produced the widening.

It is, I believe, the almost unanimous opinion of spectroscopists that the widening is, in most cases, produced by an increase of pressure. This opinion was first put forward by Frankland and Lockyer.[1] In the case of gases, the easiest way to produce the widening is by an increase in the pressure of the gas, and the metallic lines are also generally seen to widen when the density of the gas through which the spark is taken is increased. But we may also, in the case of hydrogen, for instance,

[1] *Proc. Roy. Soc.* xvii. p. 288 (1869).

widen the lines by an increase in the intensity of the discharge.[1] Those who believe that the widening of a line is due to an increase of pressure, attribute to an increase in temperature, such as is produced by an increased discharge, an influence only in so far as it raises the pressure of the gas. This opinion is supported by the fact that the sodium-lines widen rather more easily at low temperatures.

According to the molecular theory of gases, the following explanation might be given for the widening of lines.

As long as a molecule vibrates by itself, uninfluenced by any other molecule, its vibrations will take place in regular periods. The lines of its spectrum will consequently be sharp. But if the molecule is placed in proximity with others, its vibrations will be disturbed by occasional encounters. The number and strength of these collisions will depend on the pressure of the gas. Ideas analogous to these seem to have been in the minds of many writers, and it is difficult to decide where they first occurred; but we may quote a short passage taken out of a paper by Lippich,[2] in which similar views were, perhaps for the first time, clearly expressed, and in which the reference to Boyle's law is especially interesting:—

'If the pressure of a gas is increased, or if, as in the case of vapours, its properties are not those any more of a perfect gas; that is, if the length of the path during which a molecule is within the influence of another is not any more small compared to the length of the mean free path, changes in the spectrum will necessarily accompany the new state of things. . . . New vibrations will arise, the intensity of which will be the smaller, the further removed they are from the vibrations of the molecule in the ideal state. The lines of the spectrum will then appear with indistinct edges and expand the more, the more the gas deviates from the laws of Mariotte and Gay-Lussac.'

The behaviour of the two yellow sodium-lines is in many respects remarkable. It has already been mentioned that the widening seems to take place more easily at a lower temperature, but it is obviously not due to a lowering of temperature, for Profs. Liveing and Dewar[3] have observed that a layer of sodium vapour about 4 cm. thick, at atmospheric pressure, gave sharp and narrow lines, at a temperature which was lower than that of a Bunsen burner; while in the Bunsen a much smaller quantity of sodium vapour will produce winged lines. Some of the experiments described in the paper to which we have just referred are not easily reconciled with the explanation given above for the widening of lines. Profs. Liveing and Dewar describe the effects of pressure thus:—

'The effects of compressing the vapour were very remarkable. As the pressure increased the channelled spectrum speedily disappeared, then the diffused edges of the D band contracted, the band itself likewise contracting until it became a very fine pair of lines, or if the amount of sodium present was not too much, D came out bright. On letting off the pressure, the phenomena recurred in the reverse order, and the whole could be repeated several times. After compression, as long as the pressure was sustained, the D absorption remained permanently narrowed, but did not continue bright.'

[1] *Pogg. Ann.* cxxxix. p. 465 (1870).
[2] The widening observed by Stearn & Lee (*Proc. Roy. Soc.* xxi. p. 282—1873) is due to this cause.
[3] *Proc. Roy. Soc.* xxix. p. 482.

The general results of the investigation are summed up by Profs. Liveing and Dewar thus:—

'The phenomena attending the compression of the vapours, as well as those of the amalgams of varying percentages, seem to indicate that the width of the D absorption is dependent on the thickness and temperature of the absorption vapour rather than on the whole quantity of sodium present in it. Very minute quantities diffused into the cool part of the tube appear to give a broad diffuse absorption, while a layer of denser vapour of small thickness in the hottest part of the vessel gives but a very narrow absorption. This may, however, be due to the variation of temperature.'

In a previous paper, Profs. Liveing and Dewar[1] had expressed themselves as follows on the widening of lines:—

'It is apparent that the expansion of lines so often observed when fresh materials are introduced, must be ascribed to increase in the density of the vapours, not to any increase in temperature. Moreover, the length of the tube, which reaches a very high temperature in the experiments above described, is very short in the lime crucibles, and still shorter in the carbon crucible, so that the reversing layer is also short in many cases.'

There is one cause, which, as Profs. Liveing and Dewar mention, may have affected the results of the later paper: 'The results of the foregoing experiments may have been complicated by the sodium-vapour which diffused into the cool part of the vessel. We have attempted to overcome this complication by passing down into the bottle, when full, or nearly full, of sodium vapour, a platinum tube, closed at the top with a glass plate and filled with nitrogen, and observing the absorption through this tube. The nitrogen in the tube prevents, for a short time, the entry of the sodium vapour into the tube, and so, by passing the tube to different depths, the thickness of the layer of sodium through which the observations were made could be varied. It was found, in this way, that a layer of sodium-vapour, about 4 cm. thick, at the atmospheric pressure at the temperature of our furnace, gave the D absorption sharp and very narrow; but as the sodium diffused into the tube the absorption extended until it produced a broad band with diffuse edges.'

In these experiments, the light emitted by the bottom of the platinum vessel, in which the sodium was evaporated served as the source of light, the absorption of which on its passage through the vapour was observed. Now it is clear that, had the vapour been throughout of the same temperature with the vessel, the absorption would have exactly counterbalanced the radiation, and no effect would have been produced. The absorption which was produced was, therefore, entirely due only to the vapour in the parts of the tube which were cooler than the bottom. If, therefore, the effect of compression was to drive down the vapour into the hotter part of the tube, a thinning out of the absorption would be a necessary consequence, and no conclusions as to the effect of pressure can be drawn. On the other hand, it is difficult to see why, even in the compressed tube, the vapour should not have gradually diffused into the cooler parts. The disappearance of the channelled-space spectrum of sodium, however, in the compressed vapour, indicates a higher temperature, and consequently a diminished absorption.

[1] *Proc. Roy. Soc.* xxviii. p. 370.

Taking the whole of these experiments together, they do, I believe, indicate that the lines of sodium widen more easily at a comparatively low temperature; but, as they may also be seen very wide at high temperatures and narrow at low ones, they leave the original cause of the widening unexplained.

The fact that the sodium lines widen more easily at a comparatively low temperature is in accordance with the theoretical speculations we have given on the cause of the widening of lines. For in the passage quoted Lippich has remarked that an increased widening of lines would go on simultaneously with an increased deviation from Boyle's law; and that deviation will be greater when the vapour approaches its temperature of condensation.

Moreover, the widening of the sodium lines seems to take place chiefly at the temperature at which the line-spectrum changes into the band-spectrum. It will be seen further on that, according to the opinion held by most spectroscopists the band-spectrum is due to a molecule containing a greater number of atoms than that giving the line spectrum. If this opinion is true, sodium vapour ought to show a change of vapour-density as one spectrum changes into the other, similar to that which has recently been proved to exist in iodine by Victor Meyer.[1] That at the moment when the atoms or molecules of sodium have a tendency to combine with each other, the molecular forces should be affected and disturbed in such a way as to produce a widening of lines seems perfectly intelligible. At the same temperature at which the band spectrum of sodium changes into the line spectrum, Mr. Lockyer has observed some very remarkable phenomena.[2] In some parts of the tube in which the sodium was volatilized, the lines seemed to widen only towards one side, while in others they were widened towards the other side. It is, perhaps, worth mentioning, in connection with a remark by Lord Rayleigh on disturbed vibrations,[3] that the two parts of the band-spectrum of sodium lie on the two sides of the D lines.

Referring again to the effect of pressure on the widening of lines the question arises, whether for a given temperature and pressure a line may be of different width whether the molecule is placed in an atmosphere of similar or dissimilar molecules. We shall have occasion to refer to this point again, and to show that such a difference in all probability exists, and that it is not due to a mere reduction or increase in the number of luminous molecules in the line of sight. We may mention here for instance that Mr. Lockyer[4] has observed that the lines of oxygen or nitrogen may be obtained sharp at atmospheric pressure by mixing a small quantity of one gas with the other. The gas which is present in small quantities has its lines sharp. If, therefore, we observe that in putting larger quantities of sodium into a flame we widen the lines, we must take many questions into account, and not conclude merely that an increased thickness of the radiating layer has produced the result.

We finally refer to one cause which limits the sharpness of spectroscopic lines, and which was first pointed out by Lippich[5] and later by Lord Rayleigh.[6] The molecules of a gas are, in addition to their vibratory motion, endowed with a translatory motion. Those molecules which are moving towards us will, in accordance with Doppler's principle, send us

[1] *Chem. Ber.* xiii. p. 394 (1880).
[2] *Proc. Roy. Soc.* xxii. p. 378 (1874).
[3] *Phil. Mag.* xliii. p. 322 (1872).
[4] *Phil. Mag.* vi. p. 161 (1878).
[5] *Pogg. Ann.* cxxxix. p. 465 (1870).
[6] *Nature*, xvii. p. 148 (1877).

light which is slightly more refrangible than that which would be sent out by a quiescent molecule or one moving at right angles to the line of sight. On the other hand the molecules which are moving away from us will have the wave-length increased. The lines as they appear to us, and as they come from molecules moving in all directions, must have a certain width. Lippich has pointed out how this limit of sharpness which cannot be surpassed may be made use of to determine which lines in a mixture of gases are due to each component; for the heavier gas will have its lines narrower than the lighter gas. As a rule, however, the lines of a spectrum are wider than the limit given, and especially the widening of lines which we have been discussing in this chapter is of a much higher order of magnitude.

III. *Spectra of Different Orders.*

Spectra may be classified according to their general appearance. The different classes have been called orders by Plücker and Hittorf. We have first, appearing at the highest temperature, the line spectra which are best known and need no further description; we have next produced, generally at lower temperatures, the spectra of channelled spaces, the appearance of which was described in the introduction to the report on the spectra of metalloids. Continuous spectra, which need not necessarily stretch through the whole range of the spectrum, form a third order. Plücker and Hittorf have shown that one and the same element may possess at different temperatures spectra of different orders. Their results have been confirmed in the case of a great many different elements. A discussion has naturally arisen on the cause which can produce such a remarkable change of spectra. We first quote Plücker and Hittorf's[1] opinion on the subject:—

'Certainly in the present state of science we have not the least indication of the connection of the molecular constitution of the gas with the kind of light emitted by it; but we may assert with confidence, that if one spectrum of a given gas be replaced by quite a different one, there must be an analogous change of the constitution of the ether, indicating a new arrangement of the gaseous molecules. Consequently we must admit either a chemical decomposition or an allotropic state of the gas. Conclusions derived from the whole series of our researches lead us finally to reject the first alternative and to adopt the other.'

The idea that different spectra of one and the same element are due to differences of molecular structure has found considerable favour with spectroscopists. It has formed the leading idea of a large part of Lockyer's[2] work, who gave the following five stages through which spectra often pass, each stage being in his opinion due to a different molecular structure:—

1. Line-spectrum.
2. Channelled-space spectrum.
3. Continuous absorption in the blue.
4. Continuous absorption in the red.
5. Continuous absorption throughout.

Salet[3] also adheres to the opinion that different spectra are due to different allotropic states. Helmholtz, as quoted by Moser,[4] has suggested that the line-spectra may be due to atoms, the band-spectra to molecules.

[1] *Phil. Trans.* clv. p. 1 (1865).
[2] *Proc. Roy. Soc.* xxii. p. 372 (1874).
[3] *Ann. Chim. Phys.* xxviii. p. 1 (1873).
[4] *Pogg. Ann.* clx. p. 177 (1877).

The same idea was more fully developed by E. Wiedemann.[1] Even Ångström and Thalèn,[2] who do not adopt Plücker's interpretation of his experiments, remark:—

'We do certainly not deny that a simple body may in certain cases give different spectra. We may quote, for instance, the absorption-spectrum of iodine, which does not in any way resemble the system of brilliant rays of the same body, obtained by means of electricity; and we may remark moreover, that in general every simple body, presenting the property of allotropy, must in the state of incandescence give different spectra, provided that this property of allotropy exists not only in the gaseous state of the body, but also at the temperature of incandescence.

'Supposing, therefore, that there is really allotropy, even for the gaseous state, a certain absorption-spectrum must belong to every one of these allotropic states.'

An idea which has commended itself to so many different observers must possess a large amount of plausibility; but before we give various reasons and facts which seem to support it we must first refer to the only rival hypothesis which has been offered. This theory is founded on the formula given by Zöllner, and already quoted in this report, which connects the intensity of radiation of each line with the number of radiating molecules in a line of sight. Zöllner already mentioned the possibility of explaining spectra of different orders by means of it, but the idea was chiefly developed by Wüllner. Starting from the fact that band-spectra are generally given by the brush discharge, in which a great number of molecules are luminous, while the line-spectra are given by the spark, which, as a rule, is thin; also that the band-spectra often appear in the wide part of a Plücker tube, while the line-spectra are seen in the capillary part, Wüllner concludes that the thickness of the radiating layer materially affects the spectrum which is seen. The difficulty which stands in the way of this explanation lies in the fact that the maxima of light in the band-spectrum lie altogether in other places than in the line-spectra. To overcome this difficulty, as has been pointed out by E. Wiedemann,[3] we must assume a change in the emissive power with temperature different for each ray of the spectrum. Zöllner,[4] for instance, remarks:—

'But these values (the coefficients of absorption) may have for *the same wave-length* and continuous alteration of the temperature, similar maxima and minima to those which they, in fact, possess for *the same temperature* and continuous alteration of the wave-length, whereby they produce the phenomenon of discontinuous spectrum.'

Wüllner,[5] referring to the same point, says:—

'Hereby it is by no means necessary or even probable, that the absorption power increases for all rays in the same way; that, therefore, the ratio of the values of and for different wave-lengths is the same at all temperatures. As soon as such a change takes place, a displacement of the maxima of light will, or at least may, be produced. But it is only such a displacement of the maxima of light, if the bright lines of a line-spectrum are situated at other places than the maxima of illumination of a band-spectrum. In this way lines of a line-spectrum can really disappear,

[1] *Wied. Ann.* v. p. 500 (1878).
[2] *Nov. Act. Ups.* ix. (1875).
[3] *Wied. Ann.* x. 202 (1880).
[4] *Phil. Mag.* xli. p. 199 (1871).
[5] *Wied. Ann.* viii. p. 594 (1879).

while at their place in the band-spectrum an even illumination or even a decreased brightness exists compared to that of surrounding places.'

We have introduced these quotations in order to show that both Zöllner and Wüllner are aware that a mere alteration in density or thickness of the radiating layer is insufficient to account for the changes in spectra, but that a change in the absorptive and emissive properties of the gas is necessary. But it is further evident that once we assume this change we need not any more have recourse to any effects of increased number of radiating molecules; for the change itself would be sufficient to account for the phenomena, which could at most be affected, but not produced, by an increased thickness of the radiating layer. We may therefore pass over the experiments which Dr. Goldstein[1] has made in order to show that an increased thickness of spark does not produce the effects required by Wüllner's theory; and, consequently, also over the answer which Wüllner[2] has given to Dr. Goldstein's remarks.

The difference between the two explanations really comes to this: Zöllner and Wüllner assume that the radiation for a given wave-length is a continuous function of the temperature, which may be different for different wave-lengths, and for each may have maxima and minima; in other words, that the spectrum is a continuous function of the temperature. Those who adopt the rival hypothesis hold that the spectrum is within wide limits independent of the temperature, but that at certain points sudden changes in the forces which bind the atoms together take place, and that these changes are accompanied by a sudden change in the spectrum. It is likely that these changes are produced by a different number of atoms bound together in one molecule.

The change of the channelled-space spectrum of sodium to the line spectrum seems indeed to take place within narrow limits of temperature. If the absorption of that vapour is observed at low temperatures, so that the channelled-space spectrum is observed, and the temperature is gradually raised, little change is seen for some time. The D lines, though present, are sharp and faint. When a certain temperature is reached, however, these lines seem suddenly to get blacker; the bands at the same time weaken, and as they become dimmer and finally disappear, the whole energy of the motion seems to be thrown into the D lines, which now are widened into a broad black band. The change is exactly such as would be produced by a change in the molecular structure of the gas at the given temperature, and it is very likely that a change of density will be proved to take place at that temperature.

Those who adopt this view of the cause of multiple spectra, support it by the fact that in many cases where we know a change of density to occur, changes in the spectra are observed perfectly analogous to those which we want to explain. Thus, for instance, sulphur vapour near its boiling point has an anormal vapour-density; it then shows a continuous absorption; as the temperature is raised and the density becomes normal, the spectrum changes into a channelled-space spectrum. Iodine, bromine, and chlorine give us spectra of fluted bands at low temperatures; but if we pass an electric spark through them, line spectra are obtained. The recent experiments of Victor Meyer and others seem to show that the vapour density is different in the two cases.

An apparent exception occurs in the case of nitrous oxide gas, which

[1] *Berl. Ber.* 1874, August, p. 593, and *Phil. Mag.* xcix. p. 333 (1875).

[2] *Berl. Ber.* 1874 (December) and *Phil. Mag.* xlix. p. 448 (1875).

on heating changes its vapour-density and its molecular structure from N_2O_2 to NO without showing an equally marked change in its spectrum. But the exception is apparent only, for the absorption spectrum gets very much stronger as the temperature is raised, so that we have every reason to suppose that the spectrum we observe is really due to the molecule NO. We ought at the same time to expect the spectrum belonging to N_2O_2 to get weaker, and finally to disappear. As, however, it is a general rule that the spectrum of a more complex molecule lies more to the red than that of the simpler molecule, it is likely that the spectrum of N_2O_2 lies in the extreme red and ultra-red. Moser[1] indeed has found that three bands which are observed in the absorption spectrum of nitrous oxide at low temperatures disappear when the temperature is raised; these bands therefore we may ascribe to N_2O_2, which gas very likely possesses a greater number still further towards the red.

When chemical combination takes place a change in the spectrum is observed which is entirely similar to that observed in many vapours when the temperature is lowered. The spectra of the oxides, chlorides, bromides, and iodides of the alkaline earths are spectra of fluted bands. If a combination of one element with another can change a line spectrum into a channelled-space spectrum, it is quite a plausible assumption to suppose that a combination of one element with itself can produce an analogous change, and that as a rule a spectrum of channelled spaces corresponds to a more complicated molecular structure.

The question is likely to be definitely settled by a new line of investigation which has been started by Prof. E. Wiedemann,[2] and which, if followed out further, will largely add to our store of knowledge on these and similar points. Prof. Wiedemann has undertaken calorimetric measurements, in order to see whether or not heat is absorbed by a gas when a change of spectrum takes place. He has taken hydrogen gas as a first example, and measured the heat produced by a spark, equalising the same difference of potential, first when the gas gives a band spectrum, and, secondly, when it gives the line spectrum. The change from one spectrum to the other was produced by a minute change in the length of an air-break, which was introduced into the circuit. Prof. Wiedemann has found indeed that a certain amount of heat is necessary to change the band spectrum into the line spectrum, and that this heat is independent of the pressure and cross section of the tube.

These experiments would be decisive if we were quite certain of the chemical origin of the band spectrum investigated by Prof. Wiedemann. According to several spectroscopists this band spectrum is due to a hydrocarbon; so that if this is the case, Prof. Wiedemann would really have measured the heat of combination of hydrogen and carbon. Prof. E. Wiedemann will no doubt follow out this most promising line of research in the case of other gases, the spectrum of which has been investigated with more decisive results.

It is often found that metallic vapours near their point of condensation give an absorption which is continuous through part or the whole visible range of the spectrum. Even some gases like oxygen give us continuous spectra at the lowest temperature at which they are luminous. In the case of sulphur the appearance of the continuous spectrum is coincident with the anormal vapour-density, and is therefore no doubt produced by

[1] *Pogg. Ann.* clx. p. 177 (1877). [2] *Wied. Ann.* x. p. 202 (1880).

the more complete molecule. It would not be unreasonable to suppose that a similar cause produces also the other cases of continuous absorption. But Prof. Stokes [1] has suggested another cause which may produce such a continuous absorption :—

'We have reason to believe that the mere motion of matter through the ether is insufficient to produce vibrations. There must be two portions of matter exerting forces on each other in order that the ether should be thrown into agitation. In ordinary line-spectra we consider that the two portions of matter form part of the same molecule. Now, it seems possible that also two portions of different molecules should in their rapid approach towards each other, or recession from each other, cause forces in the ether which produce vibration. These latter vibrations we might expect not to take place in fixed periods, but to produce what we call a continuous spectrum. We may suppose that at the lowest temperature at which, for instance, oxygen is luminous, the vibrations in the ether are chiefly produced by this rapid relative motion of different molecules, while at higher temperatures the relative motions of different portions of one molecule might have the upper hand; the continuous spectrum in one case, and the line spectrum in the other, might thus be explained.'

IV. *The Method of Long and Short Lines.*

If the spectrum of a metal is taken by passing the spark between two poles in air, the pressure of which is made to vary, the relative intensity of some of the lines is often seen to change. Similar variations take place if the intensity of the discharge is altered, as, for instance, by interposing or taking out a Leyden jar. It is a matter of importance to be able to use a method which in the great majority of cases will give us at once a sure indication how each line will behave under different circumstances. This method we now proceed to describe.

It has often been stated, even by the earliest observers, that the metallic lines when seen in a spectroscope do not always stretch across the whole field of view, but are sometimes confined only to the neighbourhood of metallic poles. Some observations which Mr. Lockyer had made jointly with Prof. Frankland [2] led him to conclude that the distance to which each metallic line stretched away from the pole could give some clue on the behaviour of that line in the sun. In the year 1872 Mr. Lockyer [3] worked out this idea and obtained important results.

In his experiments an image of the spark was formed on the slit of the spectroscope, so that the spectrum of each section of the spark could be examined. Some of the metallic lines were then seen to be confined altogether to the neighbourhood of the poles, while others stretched nearly across the whole field. The relative length of all the lines was carefully estimated. Tables and maps are added to the memoir.

In order at once to clear up a widespread misapprehension we may mention that the longest lines (that is, those which stretch away furthest from the pole) are by no means always the strongest. Even spectroscopists use the terms, longest line and strongest line, sometimes as

[1] See note to paper by Schuster 'On the Spectrum of Oxygen,' *Phil. Trans.* clxx. p. 38 (1879).

[2] *Proc. Roy. Soc.* xviii. p. 79 (1869).

[3] *Phil. Trans.* clxiii. p. 253 (1873.) This paper will also be found to contain references to previous observations bearing on the subject.

synonymous; but those who are accustomed to work with a lens between the spark and the slit, will be able to give many instances where a faint line is seen to stretch nearly across the whole field of view, while a strong line may be confined to the neighbourhood of the pole, and is reduced sometimes to a brilliant point only.

We give a few conspicuous examples, to which we shall have occasion to refer again. The remarks refer to the length of the lines in sparks condensed by means of a Leyden jar.

Lithium: The blue line (4602·7) is brilliant but short. It is given by Thalèn as stronger than the orange line, which is much longer.

Lead: 4062·5, one of the longest lead lines, but faint, and according to Lockyer difficult to observe.

Tin: 5630·0 is the longest tin line, but it is faint, while the stronger lines near it (5588·5 and 5562·5) are shorter.

Zinc: The zinc lines (4923·8, 4911·2, 4809·7, 4721·4, 4679·5) are given by Thalèn as of equal intensity, but the three more refrangible ones are longer.

As a first result, Mr. Lockyer found that, by a reduction of pressure, some of the shorter lines rapidly decreased in length and disappeared, while the longer lines remained visible and were sometimes hardly affected. It follows, therefore, that a reduction of pressure may change the relative intensity of the lines; for a stronger, but shorter, line may disappear, while a weaker and longer one remains. We may quote, for instance, Mr. Lockyer's remark on the behaviour of the zinc lines, when the pressure is reduced.

'In the case of zinc, the effect of these circumstances was very marked, and they may be given as a sample of the phenomena generally observed. When the pressure-gauge connected with the Sprengel pump stood at from 35 to 40 mm., the spectrum at the part observed was normal, except that the two lines 4924 and 4911 (both of which, when the spectrum is observed under the normal pressure, are lines with thick wings) were considerably reduced in width. On the pump being started, these lines rapidly decreased in length, as did the line at 4679,—4810 and 4721 being almost unaffected; at last the two at 4924 and 4911 vanished, as did 4679, and appeared only at intervals as spots on the poles, the two 4810 and 4721 remaining little changed in length, though much in brilliancy. This experiment was repeated four times, and on each occasion the gauge was found to be almost at the same point, viz.:—

1st observation, when the lines 4924 and 4911 were gone, the gauge stood at	.	30 millimètres.
2nd " " " "	.	29 "
3rd " " " "	.	29 "
4th " " " "	.	31 "

'A rise to 34 millimètres was sufficient to restore the lost lines.'

Mr. Lockyer next examined the spectra given by chemical compounds: 'It was found in all cases that the difference between the spectrum of the chloride and the spectrum of the metal was: *That under the same spark conditions the short lines were obliterated, while the air lines remained unchanged in thickness.*'

Thus, for instance, when the spark was taken from zinc chloride, it did not show the lines 4923 and 4911, which, though of equal brightness with 4809, 4721, 4679, are shorter, and disappear, as we have seen, when the pressure is reduced. The three last-mentioned lines were seen.

The strongest lines of aluminium in the green and blue are not seen when a spark is taken from the chloride, but the longest lines falling between the solar H and K are seen.

Cadmium is also a striking case, for while the longest lines—5085, 4799, 4677—are seen in the spectrum of the chloride, the equally bright but shorter lines, 5378, 5338, do not appear.

Other examples are given by Mr. Lockyer.

In a subsequent paper the same author[1] has examined the spectra of the compounds of lead, strontium, barium, magnesium, and sodium with chlorine, bromine, iodine, and fluorine, and has confirmed his previous results.

An alloy behaves in the same manner as a chemical compound: 'For instance, it is possible to begin with an alloy which shall only give us the longest line or lines in the spectrum of the smallest constituent, and by increasing the quantity of this constituent the other lines can be introduced in the order of their length. This reaction is so delicate that I learnt from it a thing I had not before observed, that the least refrangible line of C, the triple line of magnesium, is really a little longer than its more refrangible compound; for the spectrum of magnesium was reduced to this one line in an alloy in which special precautions had been taken to introduce the minimum of magnesium.'

This behaviour of alloys was subsequently made the basis of a quantitative spectrum analysis by Messrs. Lockyer and Roberts.[2] Comparing the spectra of metals as observed by this method with their reversal in the solar atmosphere, Mr. Lockyer found that it was the longest line and not necessarily the strongest line which was first reversed in the sun.

Subsequent work has shown that the longest lines are also generally those which are most persistent on a reduction of temperature. The short lines, which disappeared on a reduction of temperature and were not visible in the spectrum of the chlorides, also disappear when the metal is volatilized in the arc instead of the spark. Thus the strong zinc lines 4924, 4911, which we have already mentioned, disappear in the arc. A similar remark applies to the two cadmium lines, 5377, 5336 which Profs. Liveing and Dewar[3] found to be absent in the arc, and which, as we have seen, are also absent in the spectrum of the chloride. The strong but short magnesium line 4481, is also absent in the arc, as is shown in Rand Capron's 'Photographed Spectra.'[4]

In this way many facts which have often puzzled observers, are brought under one general law. Take, for instance, the three tin lines to which we have already drawn attention. The least refrangible is the longest, but it is faint, while the two others are strong. We conclude from this that at low temperatures this faint line is stronger than the other two, while if the temperature is raised the two most refrangible lines are the strongest. This is fully confirmed by experiment. Lecoq de Boisbaudran,[5] who usually employed the spark without condenser from a solution of the metallic salts, gives the least refrangible of the lines as the strongest, and mentions that the line is weakened by the introduction of the condenser.

It is a corollary of what has been said that if we produce the reversals

[1] *Phil. Trans.* clxiii. p. 639 (1873).
[2] *Phil. Trans.* clxiv. p. 495 (1874).
[3] *Proc. Roy. Soc.* xxix. p. 402 (1879).
[4] *Photographed Spectra*, p. 35 (1877).
[5] *Spectres Lumineux*, texte p. 143; *C. R.* lxiii. p. 943 (1871).

of lines by means of laboratory experiments, we shall always first reverse the longest lines, for the order in which the lines reverse will be the order of intensities at the temperature of the reversing layer. This is also confirmed by experiment. Thus Cornu[1] has reversed the two aluminium lines between H and K. These are the longest lines, according to Lockyer, and they are also the only two lines which are reversed in the sun, although aluminium possesses some very strong lines in other parts of the spectrum. Zinc and cadmium gave similar results. The order in which the metallic lines reverse had been made the subject of a series of investigations by Liveing and Dewar, and their results tend to confirm the law given by Lockyer. Although some differences exist between the order of reversal given by Liveing and Dewar[2] and the order of length given by Lockyer, it must be left for further inquiry to see whether the differences are real. The difficulty in estimating the relative length of two lines which are not very near together, must be very great, and no doubt some of the lengths as given by Lockyer may require some corrections. Thus, for instance, Profs. Liveing and Dewar have reversed the lines 5085, 4799, 4677 of cadmium, but not 4416. This agrees with Lockyer's law, for the three first are longer than the last; but they have seen the line 6438 reversed once, and this line is given by Lockyer as shorter than 4416. But from the great intensity of 6438 in Lecoq's drawing, we should infer that it was really a long line, and that the length given by Lockyer is not correct. With the other metals, where a comparison is possible, the two lines of investigation seem to lead to the same result. Lead first reversed 4058 and subsequently 4063; this is the order of their length, though 4063 is faint at the temperature of the spark, and other much stronger lines have not been reversed.

The fact that a reduction of quantity, as for instance in an alloy, destroys the shorter though perhaps stronger lines, and leaves the longest, is more remarkable than might at first sight appear. Lecoq de Boisbaudran has studied the effect of diluting the liquids which he used as electrodes, and his results confirm Lockyer's law of the longest lines. Thus, for instance: lithium in the flame gives the red line very much stronger than the orange line. The red line is the longest, but with a concentrated solution and a spark Lecoq[3] found the orange line to be stronger; dilution with water, however, at once gave preponderance again to the long red line. A similar remark applies to the red cadmium line, 6438, which is stronger in a concentrated solution than 4677, but is weakened by dilution, being in reality a shorter line.

After having given the facts relating to the question of long and short lines, we have to see whether we can find a theoretical explanation of these facts.

The first explanation which naturally occurs to everyone would make the appearance of the long and short lines depend on the greater thickness of luminous matter surrounding the electrodes. As this thickness decreases we should expect to see more and more lines disappear and only the most persistent lines remain. These most persistent lines would be the longest. But this explanation will not account for the facts; for as we have said the longest lines are not always the strongest, and we have proved, in the first chapter of this report, that an increase of thickness

[1] *C. R.* lxxiii. p. 332 (1871).
[2] See especially *Proc. Roy. Soc.* xxix. p. 402 (1879).
[3] *C. R.* lxxvi. p. 1263.

could never change the relative intensity of two lines when the least refrangible of them is the strongest. Yet we constantly find that a less refrangible line is longer, but weaker throughout its length, than one which is situated more towards the violet. If an increased thickness of luminous matter was the cause of the appearance of the shorter line near the pole, we should have in this case, for a larger thickness, the more refrangible line the stronger; but in the centre of the spark, where there is little luminous matter and where the least refrangible long line is the only one seen, this would be the strongest. This cannot possibly be due to the effect only of decreased thickness. The fact that the longest lines are those appearing at lower temperature, though in the experiments of Lecoq and Liveing and Dewar, the quantity of luminous matter is really larger than when a high tension spark is employed, also disproves the theory that thickness of the luminous layer has much to do with the explanation of the long and short lines.

The next explanation which we shall discuss, starts from the fact that the longest lines become stronger when the temperature is reduced. A metal at low temperatures has a certain number of lines; as the temperature is increased other lines may come out, which may gain in intensity and finally surpass the original lines. These lines coming out at higher temperature would be the short lines, while the long lines would be the low-temperature lines. This explanation accounts very satisfactorily for a part of the phenomena, as for instance the disappearance of the long lines when the pressure of the gas in which the spark is taken is reduced; for the temperature of the spark will be lowered in that case. Also the fact that the longest lines are those which first reverse would flow naturally out of the explanation given. But the explanation is not complete. Why should a mixture of different elements only show the longest line of that constituent which is present in small quantities? In the case of chemical combinations we might assume that the spark having to do the work of decomposition is weakened, and that therefore the low-temperature lines are obtained. But this could no longer be if a chemical compound is replaced by a mechanical mixture. There is no reason why a spark taken from a mechanical mixture of two bodies should be cooler than one taken from each body singly. Nor could the remarkable effects of dilution, which we have already mentioned, be accounted for solely on the supposition that the long lines are low-temperature lines. We require an additional hypothesis. Speaking of the widening of the sodium lines it has already been suggested that, under the same pressure, at the same temperature, and for the same number of radiating molecules, we might have a difference in the spectrum if the molecules with which it comes into collision are molecules of the same kind only or are chiefly molecules of a different kind. I think we must have recourse to the same explanation in order to account for the facts which are now before us. For if an alloy shows us at the same temperature the longer lines only of each constituent, this may at any rate be due to the fact that the shorter lines are more easily produced by the molecules of the same kind than by those of a different kind. We must, in fact, assume, in order to account for the phenomena, that the spectrum of a molecule, when it is excited by molecules of another kind, consists of those lines chiefly which a molecule of the same kind is capable of bringing out at a lower temperature already. It would follow from this that the effects of dilution are the same as those of a reduction of temperature, which is the case. We shall speak of this

hypothesis, which may explain the behaviour of long and short lines as the hypothesis of molecular shocks, for according to it the short lines are brought out by a greater intensity of molecular shocks.

There is, however, another way of looking at these phenomena, which is advocated by Mr. Lockyer. If we carefully examine the spectrum of a metal, an image of the spark being projected on the slit of the spectroscope, and if we observe the changes which a spectrum undergoes when the temperature or pressure is altered, we cannot fail to be struck by the fact that we can generally divide the lines into two, or sometimes perhaps more than two sets, the lines in each set varying together. The question forces itself on the observer whether we have not to deal in one and the same spark with two or more overlapping spectra which vary relatively to each other. The faint lines which stretch sometimes like ghosts away from the poles into the centre of the spark, would belong to one spectrum, the short brilliant, often winged, lines, which are only confined to the neighbourhood of the pole, would belong to another.

A spark would show that set of lines strongest which belongs to the molecular grouping which is present in the largest quantity within the spark. The relative quantity of different molecules may vary with the distance from the pole, and thus a line which is strongest in the centre of the spark may be weakest near the pole. If a spark is taken from different chemical compounds, or from alloys, that set would show which is due to the particular grouping in which the element is contained in the compound. We shall speak of this hypothesis as the hypothesis of molecular combination. Both suppositions which we have mentioned, and to which we shall have to refer again, express the facts fairly well, but neither of them is free from difficulty.

V. *Other Changes in the Relative Intensity of Lines.*

We have given in the preceding pages a method by means of which the study of a spectrum shown in one given spark, will indicate to us its behaviour under a great many different circumstances. What we have said is true within sufficiently wide limits to render the method an extremely valuable one, but if the range of temperature or pressure within which our experiments are made is pushed beyond a certain point, further considerations will have to be taken into account. That the method must or may ultimately break down appears both from the experimental results which we have given and from the two possible theoretical explanations which we have mentioned. We have quoted, for instance, the behaviour of some zinc lines, when the pressure at which the spark is taken is reduced. We have seen that while three long zinc lines have remained comparatively unaffected, two equally strong but shorter lines near it rapidly decreased in length and finally disappeared. Now supposing that instead of decreasing the pressure we had increased it, the lines which rapidly decreased in length would increase more rapidly than the others, and thus, unless all lines tend towards one fixed limit, the shorter lines might finally outgrow the long ones. At that point the method of long and short lines would fail to give us correct results. Mr. Lockyer[1] has drawn attention to another cause which renders the method unsafe, if the temperature is pushed beyond a certain point. According to the two hypotheses, which, as we have seen, fairly well account for the facts,

[1] *Proc. Roy. Soc.* xxviii. p. 157 (1879).

the long lines are due to a comparatively cool state of the metallic vapour. Now, according to the theory of molecular shocks, it is an open question how the long lines behave when the temperature is increased; they may get stronger, they may not alter their intensity, or they may get weaker. According to the hypothesis of molecular combinations, on the other hand, the long lines must necessarily get weaker and finally disappear. Now, in reality, they do get weaker and finally disappear in many cases. Thus in the case of calcium, Mr. Lockyer [1] has pointed out that the blue line which is the strongest at the temperature of the Bunsen burner, of the arc, and even of a weak electric spark, gradually weakens when the intensity of the spark is increased, and finally disappears with a coil of large power. Now supposing we observed the length of this calcium line, as the spark is gradually increased. At first it would not only be the longest but also the strongest line; as the temperature is raised, the line, while still remaining the longest, would decrease in strength and would finally disappear. But it may not disappear at the same time throughout its length. If the temperature of the spark is nearly equal throughout its length, the greater quantity of matter surrounding the electrode would increase its visibility near the pole. In that case the line would shorten before it disappears. If, on the other hand, the temperature of the spark is decidedly higher near the pole, the line would first disappear there, and remain longest in the centre of the spark. It would be interesting to decide experimentally how the line actually does behave. In the mean time, we may say that, as Mr. Lockyer has pointed out, a short line may not only be the first indication of a state of things as they are at a higher temperature, but may also be due to the last remnant of the state of things as they are at a lower temperature.

We have, besides this calcium line, many other lines which disappear when the temperature is raised. Thus, of the violet rubidium lines (4216, 4202), only the more refrangible one remains in the spark. The two blue calcium lines both disappear when a condenser is used. The disappearance of these lines is always accompanied by the appearance of other strong lines.

When indium is volatilised in a flame, two lines (4509, 4101) are seen. A third line (4532) is given on Thalèn's list. According to Messrs. Clayden and Heycock,[2] this third line appears when the spectrum is taken from the chloride or from the nitrate, but disappears when the spark is taken from metallic indium. Other strong lines, however, in different parts of the spectrum, replace it in that case.

There are sometimes lines appearing at low temperatures, but behaving differently from proper low-temperature lines. These lines require further investigation, and may in some cases, at least, be due to some compounds of the metals with other elements present. We give some examples:—

Lead (5005). Mr. Brassak,[3] who was the first to investigate the differences observed in metallic spectra, when a condenser is put in or out of circuit, has noticed that in lead, without condenser, a strong line appears at the point indicated. Mr. Huggins,[4] who has found this line to be sensibly coincident with the chief line of nebulæ, has used it as a reference, by means of which he might detect a proper motion of these

[1] *Proc. Roy. Soc.* xxiv. p. 352 (1876). [2] *Phil. Mag.* ii. p. 387 (1876).
[3] *Abh. Naturf. Ges. Halle*, ix. (1864).
[4] *Brit. Ass. Rep.* (2) Bradford, 1873, p. 34.

celestial bodies. He mentions that this line appears very strong under conditions under which the other lead lines are weak. The line is given as a strong line by Lecoq de Boisbaudran, who used feeble sparks, and these facts would suggest that it is a low-temperature line of lead. But Thalèn has already pointed out that the line is only seen in the neighbourhood of the electrodes, and it figures as a short line on Lockyer's map. Also Profs. Liveing and Dewar, who have reversed the long lines of lead, do not notice the reversal of this line.

Tin (6100). Salet [1] notices that when a hydrogen flame contains a compound of tin, an orange line appears which is apparently coincident with the orange line of lithium. This line does not figure on any of the maps of the tin spectrum.

Zinc. Lockyer [2] found that zinc, volatilized in an iron tube, showed by absorption a green line. Liveing and Dewar [3] do not mention having seen this line reversed, but it is very likely the line, 5184, given by Lecoq de Boisbaudran, and proved by him not to be due to an impurity.

Sodium and *Potassium.* In the absorption spectra of sodium and potassium, lines appear in the green which were noticed by Roscoe and Schuster,[4] but referred by them to known metallic lines of these bodies; but Profs. Liveing and Dewar [5] have pointed out that they are not coincident with any known metallic lines. They have determined the wave-lengths for sodium to be 5510, and for potassium, 5730.

This is the place to notice some remarkable phenomena mentioned by Mr. Lockyer.[6] He passed a spark through an exhausted tube, below the lower pole, a piece of sodium was heated, and under the experimental conditions mentioned in the paper, the vapour above the sodium arranged itself in layers of different colours. The layer adjoining the sodium was green, and showed the green and red sodium lines without the yellow lines, while the layer above was yellow, and only showed the yellow lines, without the green and red. Mr. Lockyer also could obtain the yellowish-green lines of potassium without the red. In a subsequent paper, Mr. Lockyer [7] has opened out the question whether the spectrum of an element as it separates out of different combinations containing different numbers of atoms of the element in question, is identical or not. This is an important point, but does not come within the range of this report.

The question has been raised how far the presence of a molecule of a different kind may affect the spectrum of an element. The wide range within which Mr. Lockyer's law of long and short lines, and the elimination of impurities affected thereby, is true, shows that in a great many cases at any rate, the admixture of another atom only alters the spectrum in so far as it gives a greater prominence to the long lines; but Mr. Lockyer[8] himself had brought forward examples in which the law of long and short lines does not hold. He has obtained a spectrum of iron in which the longest manganese lines were absent, while some shorter ones were strongly represented. The question is connected with the preceding one, and its discussion is not possible at present, as the material is still too scanty.

Photometric measurements of the relative intensity of different lines

[1] *Ann. Chim. Phys.* xxviii. p. 69 (1873).
[2] *Proc. Roy. Soc.* xxii. p. 372 (1874).
[3] *Spectres Lumineux*, texte p. 138 (1874).
[4] *Proc. Roy. Soc.* xxii. p. 362 (1874).
[5] *Proc. Roy. Soc.* xxvii. p. 132 (1878).
[6] Ibid. xxix. p. 266 (1879).
[7] Ibid. xxx. p. 31 (1880).
[8] Ibid. xxviii. p. 157 (1879).

under different spark-conditions would be of great value. The relative intensity of the two strongest hydrogen lines in a series of experiments was estimated by the Greenwich observers.[1] Messrs. Frankland and Lockyer[2] had already pointed out that on a reduction of pressure the blue line (F) is the last to disappear; and Mr. Lockyer[3] afterwards pointed out that an increase of temperature made the red line stronger, In the published results of the Greenwich observations the pressure of a vacuum tube varied between 387 mm. and 100 mm. The relative intensities are given as follows:—

Pressure	$H\alpha$	$H\beta$
= 387 mm.	= 10	= 10
297	10	8
217	10	8
100	10	9

In the last case the F line was considerably narrower than before, and this may have caused the increased brilliancy.

Through the kindness of Mr. Christie, I am also enabled to give some unpublished observations on the same point made at Greenwich. A tube sealed off under a pressure of 5 mm. was employed and the effect of an air-break in the circuit was studied. Without an air-break $H\alpha$ was brighter than $H\beta$ by one-fourth; a break of one inch introduced little change, except that the whole spectrum was fainter; but when the break was increased to 1·75 inches, $H\beta$ was the brightest line, $H\alpha$ being only about two-thirds as bright. In these experiments the spark was sufficiently strong to cross an air space of 2·5 inches when the tube was not interposed. Other experiments with a somewhat stronger spark confirmed the fact that $H\beta$ is increased in relative intensity when the break is increased.

With a spark which could cross a space of 1·8 in. and a break of 1·75 in. the following observation was made:—

The spark passed occasionally with great difficulty, sometimes giving the usual crackle and at other times a sharp report, almost like a pistol. The degree of ease with which the spark passed, and the appearance of the spectrum, both varied so rapidly that it was difficult to say if one depended on the other. So far as could be ascertained, $H\alpha$ was absent when the spark passed with the greatest difficulty, and brightest when it passed most easily.'

M. Lecoq de Boisbaudran[4] mentions that an increase of temperature is often accompanied by a relatively greater increase in the brilliancy of the more refrangible rays. It is often said that such an increase is a direct consequence of the formula established by Prof. Kirchhoff. If the absorptive power of a molecule remains the same, while the temperature is increased, it follows that the blue rays gain more quickly in intensity than the red ones, but the less refrangible ones would never actually decrease in intensity, the quantity of matter remaining the same. Now such a decrease is observed in most cases mentioned by Lecoq de Boisbaudran, and there is generally no reason to suppose that the quantity of luminous matter has been reduced. We may doubt, therefore, that the observed differences in the spectra are in all cases regulated only by Kirchhoff's law; but it is a perfectly plausible hypothesis that a higher temperature is in general accompanied by a decrease in the absorptive power of the less refrangible rays. As a stronger blow often brings out

[1] *Greenwich Astron. Results*, p. 121 (1875).
[2] *Proc. Roy. Soc.* xviii. p. 79 (1869).
[3] *Proc. Roy. Soc.* xxiv. p. 352 (1876).
[4] *Spectres Lumineux*, texte p. 43 (1874).

higher tunes, stronger molecular shocks may bring out waves of smaller length. There are several instances of a regular increase in the relative intensity of the blue rays which may be ascribed to this cause. The most remarkable instance is perhaps seen in the spectrum of phosphoretted hydrogen. If a little phosphorus is introduced into an apparatus generating hydrogen, the flame will show a series of bands, chiefly in the green. The spectrum gets more brilliant if the flame is cooled. This can be done, according to Salet,[1] by pressing the flame against a surface kept cool by means of a stream of water or by surrounding the tube, at the orifice of which the gas is lighted, by a wider tube through which cold air is blown. The process of cooling the flame, according to Lecoq,[2] changes the relative intensity of the bands in a perfectly regular manner. The almost invisible least refrangible band becomes strong, and the second band, which was weaker than the fourth, now becomes stronger.

As another example of a similar change we may give the spectrum shown to a Bunsen burner. By charging the burner with an indifferent gas[3] (N, HCl, CO_2), the flame takes a greenish colour, and though the spectrum is not altered, the least refrangible of the bands are increased in intensity.

A similar change takes place, as pointed out by Mr. Lockyer,[4] in the two sets of bands of the spectrum ascribed by Profs. Liveing and Dewar to a combination of nitrogen and carbon. (See Report on the Spectra of Metalloids.)

While in the cases we have just mentioned, the phenomena are perfectly regular, and such as would flow from a general law of a more rapid increase in the intensity of the more refrangible lines by an increase of temperature, there are other cases where the changes are very irregular, as in the spectrum of tin, lithium, magnesium, the changes in which spectra we have already noticed. Zinc behaves in the opposite way: a rise in temperature increases the intensity of the less refrangible blue rays. The theory which, as we have suggested, may account for this increased brilliancy of the more refrangible rays is in accordance with the theory which explains the long and short lines by molecular shocks, but the theory of molecular combinations may also account for the facts which are now before us; for if the low-temperature spectrum is due to a more complicated molecule, it is quite in accordance with our ideas of molecular vibrations that its vibrations should take place in longer periods than those of a simpler molecule.

We have here again two hypotheses, that of molecular shocks and that of molecular combinations. Both explain the facts satisfactorily. and I do not think that one of them necessarily excludes the other. I believe, on the contrary, that a line can be drawn, and that while the regular changes observed chiefly in band spectra may be due to one cause, the often irregular changes in metallic spectra, where one set of lines disappears and another appears—often on the violet side, but sometimes towards the red—may be due to another.

It is often said that we must not ascribe the same phenomenon to two different causes, when one of them is sufficient to explain it; but the point at issue is whether the phenomena are the same in all cases. An

[1] *Ann. Chim. Phys.* xxviii. p. 57 (1873).
[2] *Spectres Lumineux*, texte p. 188 (1874).
[3] Lecoq de Boisbaudran, *Spectres Lumineux*, p. 43 (1874).
[4] *Proc. Roy. Soc.* xxx. p. 461 (1880).

advance of science has constantly led to the separation of phenomena which were formerly considered to be connected together, and we believe that the further development of the different points we have attempted to discuss, in which different observers have strongly taken up opposite opinions, will lead to the blending together of different views rather than the entire elimination of one of them.

§ 3. Emission Spectra of Rays more Refrangible than H. *Report by* W. N. Hartley, *Professor of Chemistry, Royal College of Science for Ireland, Dublin.*

Schule was the first to show that silver chloride when exposed to light transmitted through a prism was blackened more by the violet rays than by those of any other colour.[1]

Wollaston who, prior to Fraunhofer, perceived certain obscure rays in the Solar Spectrum, repeated the experiments of Schule, and found that the blackening of silver chloride extended not only over the surface occupied by the violet rays, but also to an equal degree over an equally large surface beyond the visible spectrum.[2] Shortly after the discovery of photography, Sir John Herschel resumed this subject, and remarked that different sensitive substances when exposed to the action of the spectrum behave very unequally. The maximum of chemical action takes place sometimes in one colour, sometimes in another, sometimes even outside the spectrum, and it was always observed to extend beyond the violet. Herschel unsuccessfully endeavoured to ascertain whether there are inactive spaces in the chemical spectrum, by exposing sensitised paper prepared according to the process of Mr. Fox Talbot.[3]

He showed at this time that the ultra-violet rays are not completely invisible. They produce upon the eye a sensation which is not that of violet nor of any other prismatic hue, but rather resembling what one might call a lavender-grey tint. He proposed to apply the name *lavender* to the obscure rays which produce the tint in question, in order to abbreviate the awkwardly sounding expression ultra-violet rays, and to avoid the ambiguity attached to the term *chemical rays*, which in point of fact are found in all parts of the spectrum.

M. Edmond Becquerel was more fortunate in demonstrating the existence of chemically inactive rays.[4] He showed impressions on prepared paper and on plates of iodised silver, indicating maxima and minima of chemical action. Becquerel gave the name of *phosphorogenic spectrum* to the collection of rays which show the phenomenon of phosphorescence. This spectrum extends beyond the violet, and consists of rays identical with the luminous and the chemical rays. We are indebted to Prof. Stokes for a means of studying the extremely refrangible rays by means of fluorescence.[5]

If a spectrum be projected on to certain substances such as quinine sulphate, tincture of turmeric, or glass coloured with uranic oxide, these substances become luminous, for a considerable distance beyond the region of the violet rays, and the rays thus rendered visible are always

[1] *Traité Chémique de l'Air et du Feu*, sec. 66, 1781.
[2] *Phil. Trans.* 1802. [3] Ibid. 1840.
[4] *Bibliothèque Universelle de Genève*, t. xl. 1842.
[5] *Phil. Trans.* 1852.

less refrangible than the incident rays. Prof. Stokes made drawings of certain obscure bands which were seen in that part of the spectrum lying beyond the violet, and these correspond with impressions taken on sensitised paper and prepared photographic plates by M. Becquerel. He found likewise that glass excited a considerable absorption of the more refrangible rays, but that quartz was of all bodies the one which transmitted them most easily.

By direct vision, using lenses and prisms of quartz, Prof. Helmholtz has been able to see the obscure rays, the existence of which was proved by Prof. Stokes and M. Becquerel. A very pure spectrum was observed in such a manner that a second slit shut off all the distinctly luminous rays from the eye of the experimenter. By receiving the rays on a screen saturated with quinine sulphate solution, they are rendered very plainly visible.[1] M. Esselbach has modified the process and made further observations.[2] Dr. J. W. Draper has also repeated the experiments of Becquerel and reproduced the *ultra-violet* spectrum on photographic plates.[3] This work has been continued of late years by his son, Dr. Henry Draper of New York.

M. Mascart has examined the ultra-violet portion of the solar spectrum by means of photography, and has given a drawing of a normal spectrum extending beyond H.[4] Making use of a Babinet's goniometer of very perfect construction with a prism and lenses of quartz, he substituted a photographic plate for the eye-piece. By the use of gratings traced on glass by M. Nobert he has made measurements of the wave-length of some of the ultra-violet solar rays as well as of the lines of cadmium, the spectrum of this metal being remarkable for the range beyond H, to which its rays extend.

There is a regular diminution in wave-length from the solar line H, 396·7, to 221·7, the extreme cadmium line. It was remarked that the shortest wave-length, 221·7, together with the longest of the visible undulations, A, 760, constitutes with the intermediate vibrations a scale extending nearly two octaves. In the accompanying table the wave-length of ultra-violet cadmium lines as measured by M. Mascart are given.

Wave-length of lines in that portion of the spectrum of cadmium more refrangible that the solar line H. Determined by M. Mascart:—

Numbers designating Cadmium lines	[5] Wave-length		Numbers designating Cadmium lines	Wave-length	
8	398·56	Ultra-Violet Rays.	15	—	Ultra-Violet Rays.
9	360·75		16	—	
10	346·45		17	374·34	
11	340·30		18	257·42	
12	328·75		23	231·83	
13	—		24	226·56	
14	—		25	221·76	

Dr. Henry Draper was the first who obtained photographs of the sun's spectrum completely in focus and on one plate from G (wave-length 430·7) to above O (wave-length 344·0), the photograph in this case being twelve inches in length. He succeeded on another occasion in photographing from near *h* (wave-length 516·7) to T (wave-length 303·2)

[1] *Pogg. Annal.* vol. xciv.
[2] Ibid. vol. xcviii.
[3] *Phil. Trans.* 1859.
[4] *Annales de l'École Normale*, 1864.
[5] The wave-lengths calculated by MM. Mascart and Cornu are stated in *millionths* of a millimètre, while those quoted in the foregoing report are given in *ten-millionths.*

and even further than this he has photographed the regions including E, D, C, B, a, and A, together with ultra-red rays.[1] He used a ruled speculum-plane, and in certain cases a concave speculum-mirror. The plate generally employed was of glass ruled with 6,481 lines to the inch, made by the beautiful machine constructed by Mr. L. M. Rutherford of New York. The ruled surface is $1\frac{8}{100}$ inch long and $\frac{64}{100}$ of an inch wide. It appears to be unquestionably more perfect than any similar grating made by Nobert and others. The grating being on glass gives a bright transmitted spectrum which was generally used, the remaining optical part of the apparatus being of glass achromatised according to the plan of J. W. Draper. The slit was $\frac{8}{10}$ in length and $\frac{1}{110}$ of an inch in width. The jaws of the slit made of steel were provided with a micrometer screw for separating them, and another for placing them at an angle so that occasionally photographs were taken with the slit opened to $\frac{1}{90}$ inch at the top and only $\frac{1}{130}$ at the bottom, so as to obtain a different intensity at the two edges of the spectrum. Most of the photographs were taken from spectra of the third order, which possesses the following advantages: first, it is dilated to such an extent as to give a long image, and yet is not one too faint to be copied by a reasonable exposure of the photographic plate; and secondly, the spectrum of the second order overlaps it in such a way that D falls nearly upon H, and T upon O, and these coincidences serve to determine the true wave-length of all the rays.

In order to obtain a spectrum of uniform character for rays of all refrangibilities, parts of the sensitised plate were protected by a series of diaphragms during exposure for faint groups of rays; by the removal of these at intervals the strong rays were photographed with a distinctness which could not otherwise have been attained.

The region from wave-length 400·0 to 435·0 only required about 1-10th the exposure required by that from 344·0 to 351·0. In the photograph published in 'Nature,' the line O had 15 minutes' and G $2\frac{1}{2}$ minutes' exposure to a wet bromo-iodised collodion plate, and still the former is under-exposed.

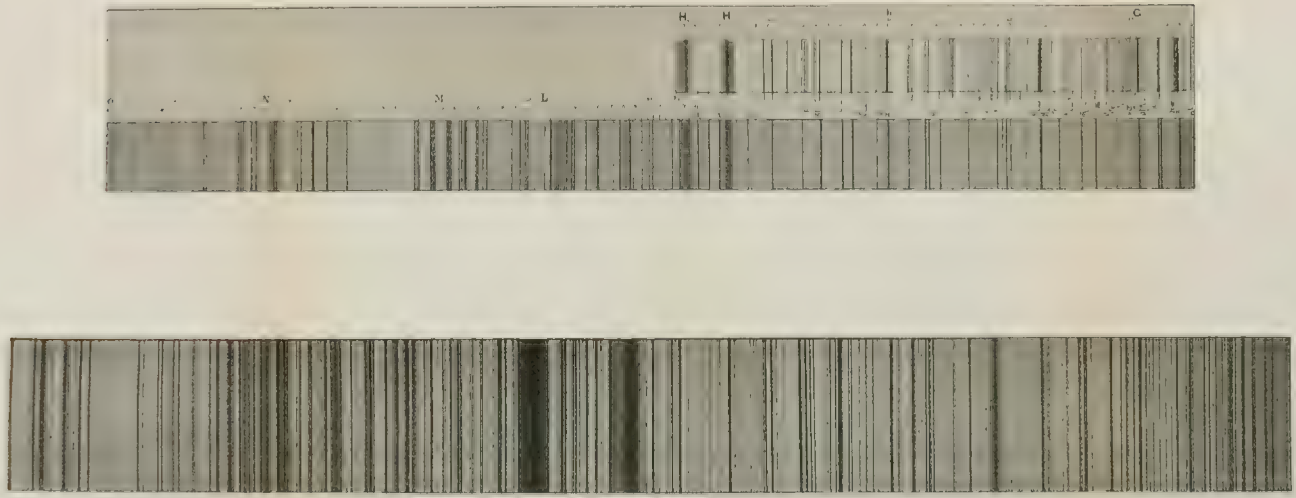
After the production of spectra which were in focus from end to end, it was necessary to attach a scale to them by which wave-lengths might be read.

Plate X. is a copy of Dr. Draper's photograph.

Using as a basis the numbers given by Ångström for the rays, D_2, b_4 and G, the wave-lengths of the principal rays on Dr. Henry Draper's photograph were calculated. Taking advantage of the fact that the second spectrum overlaps the third, the ray D being near H of the third, and F of the second being near O of the third, it is obvious that wave-lengths of three points, one at each end and one in the middle of the photograph, may be readily ascertained. As the rays D and *b* were too feeble to be easily photographed, the following device was resorted to to indicate their position, with regard to lines on the spectrum of the third order. In front of the sensitised plate and close to it, were placed two very fine steel points, one carefully adjusted to D_2 of the second order, and the other to F_2 of the second order. On developing the picture after exposing the plate to the ultra-violet spectrum of the third order, two sharply defined images of the steel points were superposed on the spectrum. The

[1] 'On Diffraction Spectrum Photography, and the Determination of the Wave-lengths of the Ultra-violet Rays, *Nature*, 1874, p. 224; also *American Journal of Science and Art*, Dec. 1873.

Photograph of the Diffraction Spectrum. (taken by Professor Henry Draper, M.D.
University of New York December, 1872



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point coincident with D_2 of the second order was found on H_2 of the third order, and the point b_4 of the second order had impressed itself near O of the third order. The ray G of the third order, the wave-length of which is known, was impressed photographically on the collodion plate.

By a simple calculation it was rendered evident that a given ray in the compound H_2 was of wave-length 393·01, and that another near O had the wave-length 344·46.

Dr. Draper ruled a fine scale with a dividing engine, and applied this to his spectrum photographs in order that the wave-length of any line could be read off at once to the 10-millionth of a millimètre.

The following remarks concerning M. Mascart's measurements are worthy of record. The line L, which he regards as single is in reality triple, and does not correspond to wave-length 381·9 but to 382·1; M is correctly designated by 372·8, but it is double; N is really at 358·3 and not at 358·0.

The spectrum above H, when compared with the region from G to H, is marked by the presence of bolder groups of lines, the most conspicuous of which are those between 382·0–386·0; 370·5–376·0; 362·0–365·0; 356·8–359·0; 349·0–353·0. Dr. Draper's fine photographs show how impossible it is to depict the relative intensities of lines in the spectrum by any other means than photography, and how groups of lines even may fail to be resolved; in his original negative there could be readily counted more than fifty lines in the group H.

In fact '*The exact composition of even a part of the spectrum of a metal will not be known until we have obtained photographs of it on a large scale.*'

M. Cornu has given a description of the solar spectrum from the line called *h* to the ray O, and has drawn a beautiful map made to the scale of wave-lengths.[1] This work was intended to be a continuation of the labours of Ångström. The spectra were observed by photography in a manner similar to that devised by M. Mascart, but as the optical apparatus was made of glass, all rays more refrangible than O (wave-length=344·11) were intercepted.

In a continuation of his experiments using more perfect lenses of quartz and Iceland spa as well as prisms of these materials, M. Cornu has succeeded in photographing the solar spectrum as far as a line called U (wave-length 294·84). Rays more refrangible than this are absorbed by the earth's atmosphere. As a reflector for the ultra-violet rays, metallic mirrors were found to be useless, therefore in order to bring solar rays into the slit of the collimator, a right-angled prism of quartz was used, the light being totally reflected from one side of the prism. The image was received on a photographic plate, a dark-slide being made to replace the eye-piece of the spectroscope.

By taking two photographs on the same plate, one below the other, the prism being turned to the right or to the left through a measured arc, the sharpness of the lines and their position near the centre of the field gives us a means of ascertaining the position of the prism corresponding to the minimum angle of deviation for any particular ray. On account of want of intensity in the rays, photographs are difficult to obtain from diffraction spectra. Diffraction-gratings on glass yield spectra continuous only as far as R. Photographs of diffraction-spectra have been

[1] *Annales de l'École Normale*, 1874.

taken by M. Cornu by means of a quartz grating; the lines ruled on the quartz numbered 60 to the millimètre. The photographic process employed was the ordinary one with wet collodion and a developer of ferrous sulphate. The collodion was salted with cadmium iodide and bromide, there being 4 parts of the former to 1 of the latter salt. M. Cornu's observations regarding that portion of the solar spectrum more refrangible than H include the following remarkable facts.

1. No single or isolated line is met with among the principal groups, such as we are familiar with in the luminous portion of the spectrum, as for instance the single lines C, D, *h* and F.

2. The groups of rays are always made up of twin lines, triplets or multiple groups, lying very close together. This occasions a certain confusion which enhances the difficulty of accurately measuring their wave-lengths. The confusion of lines is increased when diffraction-gratings are used instead of prisms, since their dispersive power in comparison with that of prisms decreases with the refrangibility of the rays.

3. The greatest extent of the solar spectrum can be photographed only in the spring-time of the year and at mid-day; at any other time the most refrangible rays are intercepted by the atmosphere.

4. Nearly all the solar rays more refrangible than H are due to the spectrum of iron. A photograph of the spectrum of this metal is a fairly accurate representation of the solar rays, and may be used as a spectrum for comparison.

5. Without exception all these rays belong to matter which enters into the composition of meteorites.

The wave-lengths of the principal lines in the solar spectrum have been measured by M. Cornu. He adopts the designation O, P, Q, R, *r* and S, given by M. Mascart to indicate certain rays.

The following numbers are the wave-lengths of the principal solar rays determined with a diffraction-grating made by Brunner.

Solar Line.	Wave-length.	Solar Line.	Wave-length.
G′	= 434·08	O	= 344·10
h	= 410·05	P	= 336·00
H	= 396·81	Q	= 328·63
K	= 393·33	R	= 317·98
L	= 381·96	r	= 314·47
M	= 372·62	Between S′ and S″	= 310·31
N	= 358·18	Trace	= 306·95

The numbers are the results of five different measurements which agreed well with each other, the means agreeing very satisfactorily with numbers obtained by M. Mascart.

Comparing the spectrum of iron with the solar rays, it was found that the incandescence of the metal caused by the action of fifty-five Bunsen's elements was much more intense than sunlight. The lines in the spectrum thus observed were for the most part coincident with the solar rays L, M, N, O, P, Q, S_2 T and U; their identity was easily recognised. The following table shows the wave-length of iron lines compared with those in the solar spectrum. The ray R is due to calcium, while other important lines belong to nickel, aluminium, magnesium and titanium. The line P cannot be recognised as belonging to any known metallic spectrum.

Plate XI. is a copy of a beautiful plate of the normal spectrum extending beyond the line H, published by M. Cornu.[1]

[1] *Annales de l'École Normale*, 1880.

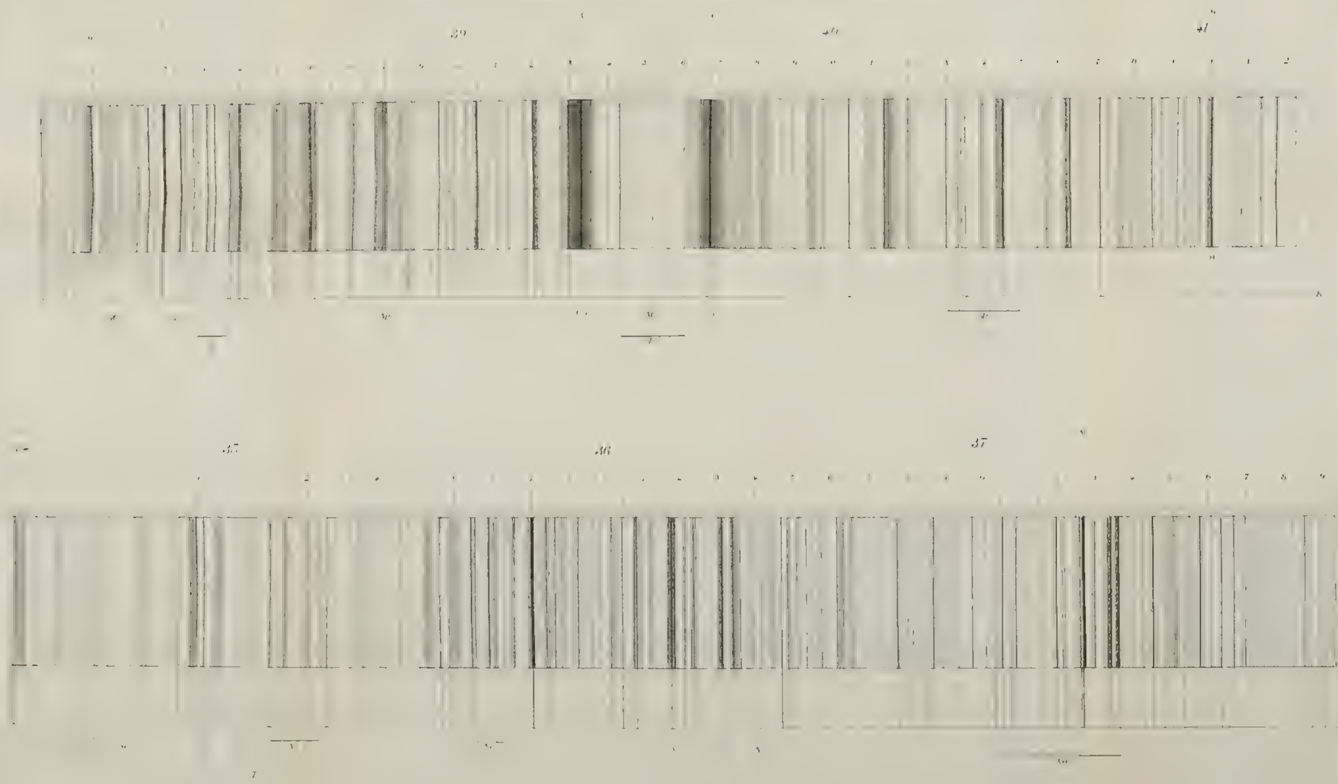

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Table showing the coincidence of Iron Lines with certain lines in the Solar Spectrum. The wave-lengths were determined by taking photographs with a Nobert's grating ruled on quartz.[1]

Designation of Solar Rays.	Wave-lengths of Iron Lines.	Wave-lengths of Solar Rays.	Previous Determinations of Wave-lengths of Solar Rays.	
	Cornu.	Cornu.	Cornu.	Mascart.
G′	—	434·08	—	—
h	—	410·05	—	—
„	407·04	—	407·04	—
H′	396·85	396·81	396·76	396·72
K	393·33	—	—	—
L	382·08	381·96	381·96	381·90
M	372·85	372·62	372·68	372·88
N	358·29	358·18	358·05	358·02
O	344·11	344·10	343·97	344·01
P	—	336·00	335·98	336·02
—	330·73	—	—	—
Q	328·76	328·63	—	328·56
—	319·62	—	—	—
R	—	317·98	—	317·75
r	—	314·47		
S_2	310·00	Between S_1 and S_2		
—	304·21	310·31		
—	302·52	(trace 306·95)		
T	302·00			
„ (2)	298·44			
—	295·43			
U	294·84			
—	293·73			
—	292·86			
—	275·39			
—	274·78			

§ 4. Absorption-Spectra of the Rays of High Refrangibility. *Report by* A. K. Huntington, *Professor of Metallurgy, King's College, London.*

In the year 1852 it was discovered by Prof. Stokes that quartz absorbs the ultra-violet rays of the solar spectrum less than glass,[2] and in 1853 he ascertained that the length of the spectrum of the electric light obtained by means of lenses and prisms of quartz was greatly in excess of that of the solar spectrum under the same conditions.[3]

These discoveries made it practicable to investigate spectroscopically the properties of the extreme rays of the ultra-violet spectrum—rays the existence of which had previously been unknown.

On June 19, 1862, Prof. Stokes and Prof. W. A. Miller communicated to the Royal Society the results of the investigations which they simultaneously but independently had made on the permeability of matter for the rays of high refrangibility, and on the spectra of metals photographed by means of quartz apparatus. The absorbent action of various solids and liquids upon the chemical rays had been described in 1843 by

[1] M. Cornu, *Annales de l'École Normale*, 1880.
[2] 'On the Change of Refrangibility of Light,' *Phil. Trans.* 1852.
[3] 'On the Long Spectrum of the Electric Light,' *Phil. Trans.* 1863.

M. Becquerel;[1] but his results were vitiated in consequence of his having used glass instead of quartz apparatus.

Both Prof. Stokes and Dr. Miller carried on their experiments by means of an induction coil and a Leyden jar; the metals for the points between which the spark passed being varied according to circumstances. The rays which escaped absorption by the substance interposed in their path were caused to pass through a quartz prism, and then focussed on a fluorescent screen or on a photographic wet plate: the former method being employed by Prof. Stokes,[2] the latter by Dr. Miller.[3]

Dr. Miller's experiments are comprised under the following heads:—

(1) *The absorption of the invisible rays by transmission through different media.*

a. By transmission through solids.
b. By transmission through liquids.
c. By transmission through gases and vapours.

(2) *The absorption of the invisible rays by reflection from polished surfaces.*

(3) *The photographic effects of the electric spectra of different metals taken in air, including*

a. Pure metals. *b.* Alloys.

(4) *Photographic effects of electric spectra of different metals produced by transmitting the sparks through gases other than atmospheric air.*

The general results having reference to (1) may be stated as follows:—

Colourless bodies which possess equal powers of transmitting the luminous rays vary greatly in permeability to the invisible rays.

Diactinic solids (that is to say, solids which are permeable to the chemical rays) preserve their diactinic power both when liquefied and when converted into vapour.

Colourless solids which are transparent to light, but exert a considerable absorptive effect upon the invisible rays, preserve their absorptive power with greater or less intensity both in the liquid and the gaseous state.

In the preparation of the various compounds for examination, much care is stated to have been taken to employ materials in a state of purity. Notwithstanding, in some cases there was reason to believe that some impurity was present which could not be detected by the ordinary tests, but which was opaque to the actinic rays. Subsequent researches by others have proved this surmise to be correct. It was found that filtration through paper sensibly impaired the diactinicity of a solution.

Dr. Miller states that he was unable to trace any special connection between the chemical complexity of a substance and its diactinic power.

As regards '*the absorption of the invisible rays by transmission through different media,*' it may be remarked that the solids examined were not of uniform thickness, and the substances experimented on in a state of solution were in the condition of saturation, and, therefore, not fairly

[1] *Annales de Chimie*, Ser. 3, vol. ix. p. 301.
[2] *Phil. Trans.* 1863. [3] Loc. cit. 1863.

comparable one with another: nevertheless some important generalisations were arrived at. No substance which could be conveniently employed for prisms and lenses was found to surpass quartz in diactinicity.

(2) '*The absorption of the invisible rays by reflexion from polished surfaces.*'

A small polished plate of the substance under experiment was supported at an angle of 45° opposite the vertical slit of the apparatus, and the source of the rays was arranged so that they should be reflected in the direction of the axis of the tube. 'It was found that no judgment of the perfection of the reflecting power could be formed from the colour of the metal.' For example, *gold* possesses the power of reflecting all the rays, even the most refrangible, very equally, though somewhat feebly. Next to gold ranks burnished *lead*, some parts of the spectrum reflected from lead being more intense than that from gold. The spectrum reflected from these two metals was found to be longer than that obtained by reflection from any other metallic surface examined. The spectrum reflected from a *silver* surface was characterised by a sudden cessation for a certain distance of the image on the photographic plate; that is to say, in a certain portion of the spectrum the rays had been absorbed, some more refrangible being transmitted. The reflection from *steel* was more *intense* than that from any other surface employed, with, perhaps, the exception of *tin*.

Speculum-metal, platinum, zinc, aluminium, mercury, cadmium, copper, and brass were also examined.

The foregoing experiments on reflection from metallic surfaces were undertaken in consequence of the difficulty experienced in obtaining a spectrum, all parts of which were even approximately in focus in the same plane. The results were not, however, considered favourable to the substitution of a speculum for a lens.

(3) *Photographic effects of the electric spectra of different metals taken in air.*

(*a*) Pure Metals. Although each metal was found to have a distinctive spectrum, as in the case of the ordinarily visible rays, yet it is remarkable that no important difference is apparent in the less refrangible end. The photographic lines of the air-spectrum are most marked in the less refrangible portion, whilst the characteristic lines of the metals are particularly evident in the more refrangible parts. The more volatile metals gave the most intense spectra—those of bismuth, antimony, cadmium, zinc, and magnesium being the most prominent in this respect. A certain similarity was observed in the spectra of allied metals; this was the case with the three last-named metals, and also in the case of iron, cobalt, and nickel, and with bismuth and antimony, as well as with chromium and manganese. In consequence of imperfections in the methods of experimenting, the true relative length of the spectra was not accurately determined.

(*b*) Spectra of Alloys. Dr. Miller states that 'When equal weights of two metals are employed (tin and lead, for example, or cadmium and lead) a compound spectrum exhibiting the lines due to both metals is produced; and it is not always the more volatile metal that predominates.'

(4) *Photographic effects of electric spectra of different metals produced by transmitting the sparks through gases other than atmospheric air.*

The gases to be examined were passed through a glass tube which enclosed the electrodes; on one side the part opposite the metal-points was cut away and replaced by a thin piece of quartz. The general results of these experiments on the invisible rays are in harmony with those already obtained for the visible rays by MM. Ångström,[1] Alter,[2] and Plücker.[3] They may be summed up as follows:—

1. Each gas tinges the spark of a characteristic colour; but no judgment can be formed from this colour of the kind of spectrum which the gas will furnish.

2. In most cases, in addition to the lines peculiar to the metal used as electrodes, new and special lines characteristic of the gas, if elementary, or of its constituents, if compound, are produced. When compound gases are employed, the special lines produced are not due to the compound as a whole, but to its constituents.

Prof. Stokes's experiments on the fluorescent spectra of metals and the diactinicity of solids and solutions corroborate the results obtained by Dr. Miller. In his method of experimenting the substance to be observed is introduced into the solvent, and the effect on the fluorescent screen watched as solution gradually takes place; in this way he was enabled to seize the most characteristic phase of the absorption, and registered it on paper by means of a pricking instrument devised by him for the purpose.

Some interesting results were also obtained by him regarding the *Absorption of the invisible rays by Alkaloids, Glucosides, &c.* He found that these bodies were intensely opaque for a portion of the invisible rays, the mode of absorption being generally highly characteristic. The solvents used were water, dilute sulphuric acid, dilute hydrochloric acid and ammonia: all of these being sufficiently transparent to the rays under examination, to answer the purpose. The effect of acids and alkalies on the glucosides presented one uniform feature: when a previously neutral solution was rendered alkaline the absorption began somewhat earlier, when rendered acid somewhat later. In the case of quinine and the other bases observed, with one exception, the absorption, if altered at all, was changed in an opposite manner to that in the case of the glucosides when the base is set free by ammonia. Bands of absorption also appeared when neutral substances were examined, *e.g.*, in the case of coumarine and paranaphthaline.

In addition to experimenting on several minerals as to their transparency for the rays which give rise to fluorescence, Prof. Stokes examined them also for the property of fluorescence itself. His researches in this direction were rewarded by some interesting results. He found that adularia exhibits a pair of bluish dots—the images of the tips of the electrodes—when the rays of highest refrangibility are focussed on it; as the same phenomenon was observed with colourless felspas from different localities, it is doubtless a property of silicate of alumina and potash. The other case of interest relates to a particular variety of fluor-spar found at Alston Moor. The specimen, when exposed to the spark passing

[1] *Poggendorff's Annalen*, 1855, Bd. xciv. s. 141.
[2] *Silliman's Journal*, 1855, vol. xix. p. 213.
[3] *Poggendorff's Annalen*, 1859, Bd. cvii. s. 497.

between aluminium-points, in addition to the usual blue fluorescence exhibited a reddish colour, extending not nearly so far into the crystal; this reddish fluorescence was ascertained to be produced by the rays of extreme refrangibility. Prof. Stokes found that as the distance between the electrodes was diminished the reddish fluorescence appeared to increase. Similar experiments with this crystal lead him to the conclusion that the proportion of rays of extremely high refrangibility is decidedly greater for the spark at the contact-breaker than for the secondary discharge.

Arc-discharge and lines of blue negative light.—When the electrodes are made to nearly touch, and the spark passes with little noise, a new set of strong lines make their appearance in the invisible region of moderate refrangibility. Although in this mode of discharge the jar has not much influence, the lines in question are better seen when it is suppressed altogether. Under these circumstances the visible discharge is very insignificant, but a very considerable effect is produced in the invisible region.

From the publication of the papers just referred to until the year 1874, we find nothing recorded which materially adds to our knowledge of the more refrangible rays of the ultra-violet spectrum. About this time M. J. L. Soret constructed a spectroscope provided with a fluorescent eyepiece.[1] The modification introduced consists essentially in placing a transparent and fluorescent substance at the focus of the object-glass, and, in order to view the spectrum to advantage, having an eyepiece inclined to the axis of the telescope. By means of this spectroscope (still further slightly modified) M. Soret examined the solar spectrum at different altitudes.[2] He found that the *intensity* of the ultra-violet spectrum is notably greater at high elevations than at the sea-level, but that the spectrum does not extend further. Similar observations were made by Janssen in India: he remarked that at a great elevation it was possible to distinguish by direct vision ultra-violet rays, which, with the same instrument, could not be distinguished at the level of the sea. M. Soret draws the inference that it is the sun's atmosphere, and not that of the earth, which absorbs the solar rays of a smaller wave-length, a conclusion which is, he says, already admitted by some savants, and which is confirmed by the fact that the light emitted by the edge of the sun exerts a less energetic chemical action than that emanating from the centre. Our atmosphere exerts a twofold absorbing action: the one, due to the vapour of water and to gaseous substances, is elective and gives rise to atmospheric bands; the other is continuous, and acts with an increasing energy the more refrangible the rays. The latter is probably due to solid or liquid particles in suspension in the air, for on the sky becoming clouded the ultra-violet rays lose much of their intensity, and when the sun is near the horizon they disappear altogether.

By the publication by M. Soret in 1878, of the results of further investigations, our knowledge of the extremely refrangible rays was somewhat advanced. He examined many of the substances previously investigated by Professors Stokes and Miller, and also a considerable number of other bodies. As, however, in most cases the substances employed had not been specially prepared, the conclusions to be drawn

[1] *Archives des sc. phys. et nat.* 1874, t. 49.
[2] *Loc. cit.* t. lvii. 1876.

from the results were in consequence necessarily limited. *Apparatus employed:*—a Ruhmkorff's coil, a magneto-electric machine, and four Leyden jars were so arranged as to give a spark 15 centimètres long. The spectroscope with a fluorescent eyepiece was employed in this and subsequent investigations of a similar nature.

Transparency of Quartz, &c.

The observation by Prof. Stokes, that quartz when beyond a certain thickness does not transmit the extreme rays was confirmed, a gradual absorption being found to take place as the thickness increased; he also found that a prism of Iceland-spa absorbs the very extreme rays. From a comparison of the transparency of quartz and water, the conclusion was arrived at that 'the coefficient of extinction for the rays of the refrangibility of the ray 32 is feebler for quartz than for water; but for the rays 27–31 this coefficient is stronger for quartz.' It was ascertained that the transparency of solutions filtered through paper was not impaired provided the paper had been previously washed with water containing a little hydrochloric acid, and then with pure water.

If the thickness of the layer through which the rays have to pass be increased, the very refrangible rays are more and more intercepted; but the rate of diminution varies much with different substances. Chromates and nitrates were observed to cause absorption bands in the ultra-violet region. The sulphates of didymium and cerium, and commercial ammonia were also found to occasion absorption bands, that in the case of ammonia being, however, due to some impurity ordinarily present in ammonia derived from gas-liquor.

MM. J. L. Soret and A. A. Rilliet have since examined the ultra-violet absorption-spectra of the ethereal nitrates and nitrites with the view to ascertain whether these substances behave in the same way as metallic nitrates and nitrites.[1]

The nitrates of ethyl, butyl, and amyl were found to absorb energetically the ultra-violet rays; but they did not produce the characteristic absorption-bands observable in the case of the metallic nitrates. The ethereal nitrates are, however, more transparent than the metallic nitrates for the rays 12–14, but less so for 17–20, being again more transparent for the extreme rays. The vapours of the ethereal nitrates exhibit considerable absorptive power even at the ordinary temperatures.

Nitrites of amyl and ethyl absorb energetically the ultra-violet rays. Six bands, about equidistant, are apparent between H and R. The vapours give the same bands. The alkaline nitrites, although very absorbent for this part of the spectrum, do not give the same absorption-bands.

An examination of the absorption-spectra of the bases in gadolinite by means of the solar rays, an Iceland spa prism being used, has led M. Soret to the conclusion that some of the bands in the ultra-violet region are not due to yttrium, erbium, or terbium, but to the new base discovered by Delafontaine.[2] In a subsequent communication on the absorption-spectra of didymium and some other substances obtained from samarskite,[3] a comparison is given between a chloride of didymium from samarskite, and one obtained from a different source. The former exhibited differences, supposed to be due to the presence of the new earth in small quantity. Further on in the same volume (page 521) we find

[1] *Comptes Rendus*, t. lxxxix. p. 747. [2] Ibid. t. lxxxvi. p. 1062.
[3] *Loc. cit.* lxxviii. p. 422.

some comments on the identity of the earth called X by M. Soret, holmium by M. Clève, and philippium by MM. Delafontaine and Marignac.

With the view to ascertain whether the centre of the eye is transparent to the rays of extreme refrangibility of the induction spark, M. Soret has made experiments on the eye of the bullock, the calf, and the sheep. He finds that the limit of transparency for the aqueous and vitreous humours, with a thickness of one centimètre, is the ray U ($\lambda = 294{\cdot}8$, Cornu); with a thickness of 2–3 millimètres 16–20 (cd) are intercepted, but 22–24 are transmitted: *i.e.* there is an intermediate absorption or absorption-band. A diagram is given showing the maximum transparency for different thicknesses.[1] As it appeared probable that the absorption was due to albuminoids contained in the humours, the curve due to white of egg was examined; it is shown in the diagram. These two curves present considerable analogy in form, but the absorption-band of the latter is displaced in the direction of the less refrangible end of the spectrum. Defibrinized blood also gives an absorption-band similar to that of white of egg. The cornea and the crystalline are more absorbent than the aqueous and vitreous humours. The thinnest possible slice of the crystalline cuts off the rays of greatest refrangibility. The curve due to the crystalline diluted with water approached more nearly to that of white of egg than to that of aqueous humour. The eye of living man is certainly more transparent for these rays; but this is due in all probability to its smaller dimensions. The comparison is also made more difficult by the rapidity with which the tissues alter after death.

In any case it appears probable that the eye as a whole absorbs all the rays more refrangible than U, *i.e.* the most refrangible ray of the fluorescent solar spectrum.

M. Cornu, when determining the wave-lengths of the solar spectrum, in order to construct a map, made some object-glasses which were achromatized by using a converging lens of quartz, and a diverging lens of Iceland spa.[2] There is not, however, the proper relation between the dispersion of these two substances to give a very perfect achromatism, and in addition Iceland spa absorbs somewhat energetically the most refrangible rays. M. Cornu discovered a substance at least as transparent as quartz, and which has a law of dispersion so well in harmony with that of quartz that we are enabled to obtain a system of lenses of which the achromatism is nearly perfect. This substance is a colourless variety of fluor spa from Switzerland. With this arrangement he obtained, on one plate, with satisfactory sharpness of definition, the spectrum of all the photographic rays from the three blue rays of zinc to the ray No. 32 of aluminium.[3] It may be pointed out that the great transparency of fluor-spa for the rays of highest refrangibility had previously been referred to by Professors Stokes, Miller, Hartley, and Huntington. As it crystallises in the tesseral system it might probably be used with advantage in special researches to avoid double refraction.

By means of the apparatus described above, M. Cornu has carried out some important investigations regarding the limit of the ultra-violet rays of the solar spectrum at different elevations.[4]

He finds that the limit of the solar spectrum varies with the state

[1] *Comptes Rendus*, t. lxxxviii. p. 1012. [2] Ibid. t. lxxxvi.
[3] *Arch. des Sc. phys. et nat.* t. ii.
[4] *Comptes Rendus*, t. lxxxviii. pp. 1101 and 1285.

of the atmosphere, the nature of the collodion, and the duration of the exposure; but, if the finest days be chosen, and a collodion of constant composition be used, the length of the exposure being always the same, then comparable series are obtained. For example—

Observations made at Courtenay (Loiret), 11th Sept. 1878. Lat. 48° 2′ 2″; wet plates.

$10^h\ 30^m$ a.m.	295·5	$3^h\ 40^m$ p.m.	302·0
0 . 2 p.m.	295·0	4 17 „	304·5
1 18 „	295·5	4 38 „	307·0
1 50 „	297·0	5 2 „	312·0
3 9 „	299·0	5 14 „	315·0 ?

The length of the spectrum is expressed in wave-length by comparison with the diagram constructed by M. Cornu from observations made in 1877.[1] The table given above indicates that the length of the spectrum diminishes with the height of the sun; which tends to prove, M. Cornu thinks, that atmospheric absorption is the cause of the limitation.

Therefore, on diminishing the depth of the atmosphere, by making the observation at a greater elevation, the length of the photographic spectrum ought to be increased. From calculations based on experiments made at a small elevation M. Cornu concludes that the limit of the spectrum would be altered by an amount equivalent to one-millionth of a millimètre for a rise of about 663 mètres. He deduces from his experiments a formula which expresses the law governing the increase in length of the spectrum at different heights. This formula shows, says M. Cornu, that if the principles which have served to establish it are exact, we are condemned never to know a considerable portion of the spectrum—perhaps the most interesting.

The spectrum of iron in the voltaic arc extends at least to radiations of which the wave-length $\lambda=200$, whereas the most favourable observations of the solar spectrum have only reached $\lambda=293$.

The consideration of the temperature of these two sources leads one to think that the solar spectrum ought to extend beyond the limit of the spectrum of the voltaic arc.

From theoretical considerations, based on these observations and the formulæ deduced from them, M. Cornu concludes that if this absorption really takes place it ought to be sensible for small thicknesses of atmosphere; in other words, there ought to exist rays of so short wave-length as to be absorbable by a small thickness of air.[2] He finds that with the solar rays approximately the following results should be obtained:—

10·00m. of air at 760mm. would extinguish rays the wave-length of which is	211·84
1·00m. „ „ „ „ „ „	184·21
0·10m. „ „ „ „ „ „	156·58

The sparks produced by a powerful induction coil approximately fulfil the double function of furnishing very intense and very refrangible radiations. This is particularly the case with the extreme rays of aluminium, designated 30, 31, and 32 by M. Soret, and the wave-lengths of which were found by M. Cornu to be:—

Ray 30	198·81	32 triple	186·02 strong.
„ 31 double	193·35 strong.		„ very weak.
	192·87 weak.		185·22 not so strong.

[1] *Comptes Rendus*, t. lxxxvi. [2] Ibid. t. lxxxviii.

These groups are developed when examined either by photography[1] or by fluorescence, with the aid of a spectroscope having lenses and prisms entirely of quartz or of fluor-spa, and focussing at a mètre; the order of brilliancy being 30, 32, 31.

The following experiments demonstrate that the intensity of the extreme rays is modified considerably by atmospheric absorption in the manner indicated by the formula.

With a spectroscope (comprised of one prism and an object-glass) focussing at six mètres, the ray 32 was invisible, the feeblest ray, 31, being still quite distinct. On adding a collimator, so as to reduce the distance to 1·50m., the ray 32 again became visible, notwithstanding the absorption due to the additional object-glass.

To complete the demonstration, M. Cornu had a spectroscope constructed focussing at 0·25m. With this apparatus the ray 32 had a superior intensity to ray 30; so that the order became 32, 30, 31. Still not satisfied, he arranged, between the collimator and the prism of the spectroscope, a tube four mètres long, closed at its two extremities by fluor spa. When the tube is full of air no trace of 32 is visible, but if a vacuum be gradually made, 31 gains in intensity, 32 soon appears, and finally surpasses in intensity 31. As the air is readmitted the phenomena repeat themselves in inverse order.[2]

In order to put this property of the atmosphere to the test of further direct experiment, M. Cornu carried out a series of experiments of great interest in the Alps. The following are the results of these experiments, which were made under particularly favourable conditions :—

Riffelberg.						Viège.		Rigi.	
July 24.		July 25.		July 26.		July 28.		August 1.	
True time	λ	True time	λ	True time	λ	True time	λ	True time	λ
11h 52m	294·3	9h 5m	294·3	6h 51m	301·2	9h 39m	295·7	8h 08m	298·8
0 59	294·7	9 29	294·5	7 9	300·1	10 2	295·7	8 48	297·0
1 18	,,	9 55	294·3	8 55	297·4	10 26	295·4	9 20	295·7
1 44	294·5	10 17	294·0	9 41	295·7	11 25	295·4	11 24	294·8
		11 16	?	10 14	293·5	11 45	295·4	11 49	294·8
		11 23	294·0	10 52	293·4	0 24	295·4	0 17	294·8
		11 51	294·0	11 39	293·7	0 47	295·4	0 44	294·8
		0 41	293·2	11 58	293·7	1 20	295·4	2 21	295·1
		1 9	293·4	0 33	294·7	2 0	295·4	3 41	297·7
		1 33	293·8	1 9	294·7	3 6	296·4	4 17	300·6
		5 22	301·5	1 44	294·7	3 47	298·9		
		5 43	303·1	5 2	300·4	4 27	300·9		
		6 7	305·7			5 3	302·0		
						5 32	304·1		

The most remarkable series is that of July 25 at Riffelberg. The curve traced by taking for ordinates the logarithm of the sine of the true height of the sun, and as abscissæ the wave-lengths for the limits observed, is nearly an absolutely straight line. The deviation in the curve for the Rigi corresponds to the time at which there was mist. Expressed in wave-lengths, the extreme limits of the ultra-violet solar spectrum were as follows :—

[1] When wet-plates are used they should be washed with pure water after sensitising, as nitrate of silver is very opaque to the extreme rays.

[2] *Comptes Rendus*, t. lxxxviii. p. 1289.

	λ	Altitude.
Riffelberg . .	293·2	2570m
Rigi . . .	294·8	1650
Viège . . .	295·4	660
Diff. (Riffel-Viège)	−2·2	1910

The conditions of the foregoing experiment were obviously more favourable to the correct determination of the influence of different thicknesses of atmosphere in absorbing the extreme rays than were those previously made at low levels. It would appear, then, that the increase of length expressed in wave-lengths is about one-millionth of a millimètre for 900m. within the limits experimented on by M. Cornu.

Notwithstanding the failure on the part of Dr. Miller to trace any special connection between the chemical complexity of a substance and its diactinic power, Mr. W. N. Hartley, in the year 1872, having at his disposal the apparatus which had been used by Dr. Miller, determined to repeat, in a more complete and comprehensive manner, the experiments which had been made by that investigator. He was led to this determination by the consideration that all the characteristic physical properties of organic substances are dependent on their molecular constitution; and he inferred that if a large number of bodies of similar constitution were examined, many of which would be metameric substances, such as the ethereal salts of the organic acids and homologous series of the normal alcohols and acids, evidence might be forthcoming of the influence of impurities and the variations in the absorption of the invisible rays caused by each increment of CH_2 in the molecule. In the carrying out of this research, Mr. A. K. Huntington was associated with Mr. Hartley; their joint labours are recorded in the 'Phil. Trans.' part I., 1879, and in the 'Proc. Roy. Society,' 1879.

The relative absorptive power not being affected by the physical condition of matter (Miller), the inconvenience of making observations on equal volumes of organic substances in a state of vapour was avoided, it being easy to arrive at the maximum absorption due to a molecule of a substance by taking into account its specific volume in the liquid state, and making the layer of liquid proportionally thick, or by dissolving the substances in solvents of known transparency in the ratio of their molecular weights.

The method of experimenting.

After careful trial of the methods of studying the ultra-violet rays, preference was given to the photographic method. Rays which cause a very indistinct effect, or no effect at all, on a fluorescence screen, will on a properly prepared photographic plate produce a satisfactory image. A piece of uranium glass is extremely useful in focussing; a strip of glass coated with gelatine in the solution of which some æsculine has been dissolved, answers equally well. To observe the visible and ordinarily invisible rays simultaneously by reflected light, a piece of paper steeped in a solution of æsculine, to which a little ammonia has been added may be employed.

In the course of the investigation it was found necessary to modify in many important details the original apparatus. In order to prevent the ignition of volatile liquids and to better concentrate the light on the slit, the liquids under examination were placed at the back of the slit, in a box forming a prolongation of the collimator tube. A means of exhausting

vapours which might become diffused in the tube was provided. The metal employed to produce the spectrum has varied according to circumstances, but for most purposes nickel was preferred. In many cases, especially where absorption-bands occur, it is desirable to photograph with the slit wide open; in this way a continuous and more uniform spectrum is obtained. Wet-plate photography did not give satisfactory results; the more refrangible end of the spectrum either not photographing or being very weak, and in a small room the ozone generated by the electric discharge causes a deposit of silver on the plate directly the developer is applied. Accordingly, recourse was had to dry-plates; gelatine plates were found to be the most generally serviceable. The lines of zinc, cadmium, and aluminium were employed to define the region of absorption.

After examining a very large number of specially purified substances, and recording the results by diagrams which accompany the report, the following generalisations were arrived at:

(1) The normal alcohols of the series $C_n H_{2n-1} OH$, are remarkable for transparency to the ultra-violet rays of the spectrum, pure methylic alcohol being nearly as much so as water.

(2) The normal fatty acids exhibit a greater absorption of the more refrangible rays of the ultra-violet spectrum than the normal alcohols containing the same number of carbon atoms.

(3) There is an increased absorption of the more refrangible rays corresponding to each increment of CH_2 in the molecule of the alcohols and acids.

(4) Like the alcohols and acids, the ethereal salts derived from them are highly transparent to the ultra-violet rays, and do not exhibit absorption-bands.

Examination of Substances containing the Benzene Nucleus.

In the examination of substances represented by a formula containing a closed chain of carbon atoms doubly linked together, it was shown that all such bodies are highly adiactinic, the hydrocarbons being least so. Prof. Stokes has pointed out that one of these substances, salicine (a glucoside of saligenin) during the process of dilution causes an absorption-band in the spectrum of the transmitted rays. It was thought worth while to examine allied substances, such as phenol, salicylic acid, etc., and ascertain whether they also produce absorption-spectra. The following points of interest were made apparent by the results of this examination of benzene and its derivatives:—

(1) Benzene and the hydrocarbons, alcohols, acids, and amines derived therefrom, are remarkable—first, for their powerful absorption of the most refrangible rays; secondly, for the absorption-bands made visible by dissolving them in water or alcohol; and thirdly, for the extraordinary intensity of these absorption-bands even in very dilute solutions.

(2) Isomeric bodies containing the benzene nucleus exhibit widely different spectra, inasmuch as their absorption-bands vary in position and in intensity.

(3) The photographic absorption-spectra can be employed as a means of identifying organic substances, and as a most delicate test of their purity. The curves obtained by co-ordinating the extent of dilution, or in other words the quantity of substance, with the position of the rays of

the spectrum transmitted by the solution, form a strongly marked and highly characteristic feature of very many substances.

In consequence of the satisfactory results which they had obtained, Messrs. Hartley and Huntington thought it worth while to make a special examination of essential oils.[1] In addition to the scientific interest which these bodies possess, many have considerable commercial value, and consequently are subject to adulteration.

It is now well known that essential oils consist for the most part of isomeric hydrocarbons, which may be divided into three polymeric groups, having the composition represented by the formulæ—$C_{10}H_{16}$—$C_{15}H_{24}$—$C_{20}H_{32}$.

To the first class belong the hydrocarbons derived from turpentine, orange, nutmeg, myrtle, and others; the second group includes the hydrocarbons from rosewood, cubebs, calumus, cascarilla, patchouli, and cloves. The third group is represented by colophene. Though of unknown constitution, these bodies exhibit a close relationship to benzene derivatives.

The report on this investigation contains twenty-five diagrams having reference to about fifty specimens which had been examined. In the examination of the following bodies no absorption-bands were discovered, but the absorption of the extreme ultra-violet rays was found to be greater the higher the number of carbon atoms in the molecule: australene, terebene,[2] terebenthene, hesperidene, cajputene, dihydrate, the oils of lign aloes, Indian geranium, santal wood, cedrat, birch bark, juniper, rosemary, rosewood, lavender, vitivert, turpentine, cubebs, patchouli, citronella, elder, melaleuca ericifolia, and cedar wood, the hydrocarbons from cedrat, nutmeg, carraway, and menthole, otto of rose, and otto of citron.

The presence of cymene in small quantity was indicated by absorption-bands in the case of the hydrocarbons from thyme, lemon, and nutmeg, the blue oil from patchouli, and in one specimen of carraway hydrocarbon.

The following bodies cause powerful absorption-bands, and are, there can be but small doubt, composed largely of some benzene derivative: oils of bay, thyme, peppermint, bergamot, cloves, aniseed, and cassia, carvole, myristicol, and otto of pimento. It is generally admitted that the oils of bay, pimento, and cloves contain eugenol, $C_6H_3 . OH . OCH_3 . C_3H_5$; oil of aniseed, anethol, $C_6H_4 . OCH_3 . C_3H_5$; oil of thyme, thymol, $C_6H_3 . OH_3 . C_3H_7$. Some other oils, such as bergamot and oil of peppermint, as likewise the bodies menthole, carvole, and myristicol, have an unknown constitution. The three latter substances are said to be isomeric.[3] A special interest is attached to their examination, since the character of the spectra they transmit appears to show that the nucleus of menthole is a terpene; while the benzene ring is the inner basis of carvole and myristicol. An examination of the absorption-spectrum of myristicol throws further light on the nature of this substance. On reference to the diagram, we find that the absorption-band is not well-defined, and that a comparatively small amount of dilution has sufficed to eliminate it. Now these are the characteristics of an absorption-spectrum due to a mixture of two substances, one of which only is capable of causing an intermediate absorption.

[1] *Proc. Roy. Soc.*, 1880.
[2] Since shown to be chiefly camphene (*Journ. Chem. Soc.* vol. xxxv. p. 758).
[3] *Jour. Chem. Soc.*, Gladstone, vol. xxv. p. 1.

The refraction-equivalent of myristicol[1] agrees well with numbers characteristic of compounds of the aromatic series. It may be inferred from these facts taken together that this substance is composed largely, but not wholly of some benzene derivative.

The refraction-equivalent of carvole is also abnormal, like that of bodies of the aromatic series. Its absorptive power is remarkable, it still being very considerable even when the substance is diluted to 1 in 300,000; whereas the absorption-band in the case of myristicol has practically disappeared at about 1 in 20,000. Similarly bergamot may be shown to be a mixture of a terpene with a benzene derivative, and oil of peppermint to be composed entirely, or nearly so, of a benzene derivative.

The following is a summary of the conclusions drawn regarding the terpenes :—

1. Terpenes, with the composition $C_{10}H_{16}$, possess in a high degree the power of absorbing the ultra-violet rays of the spectrum, though they are inferior in this respect to benzene and its derivatives.

2. Terpenes, with the composition $C_{15}H_{24}$, have a greatly increased absorptive power.

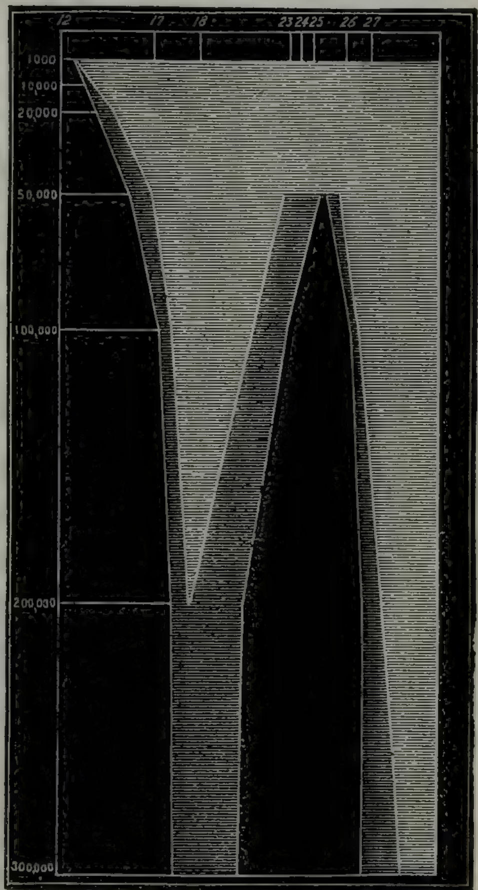
3. Neither the terpenes themselves, nor their oxides nor their hydrates, exhibit absorption-bands under any circumstances when pure, but always transmit continuous spectra.

4. Isomeric terpenes transmit spectra which generally differ from one another in length, or show variations on the substance being diluted.

5. The process of diluting with alcohol enables the presence of bodies of the aromatic series to be detected in essential oils; and even in some cases the amount of these substances present may be approximately determined.

The accompanying diagram may be taken as typical of the absorption-spectra referred to. The light portion represents the region of absorption.

Oil of aniseed. B.P., 220–223° C. The absorption-band is due to anethol, $C_6H_4 \begin{cases} OCH_3 \\ C_3H_5 \end{cases}$



Absorption still strong at 300,000.

The results so far obtained by Professors Hartley and Huntington naturally led to the consideration whether substances with two doubly-linked adjacent carbon atoms exhibit any bands in their absorption-spectra, and other similar questions. These points have been independently investigated by Prof. Hartley, since his appointment to the Royal College of Science, Dublin.[2]

[1] Gladstone, *Jour. Chem. Soc.* vol. xxiii. p. 149.
[2] *Chem. Soc.*, read June, 1880.

As representatives of bodies with two doubly-linked adjacent atoms, ethylene, amylene, and allyl-alcohol were examined: no absorption-bands were seen. To ascertain the effect of treble-linking, two carbon atoms, acetylene and valerylene, were examined: again, no absorption-bands were apparent.

It appears probable then that in no case do carbon atoms arranged in an open chain give rise to absorption-bands. The arrangement of the H and O atoms has not been found to affect the question.

With hydrocarbons containing at least six atoms of carbon and their derivatives there are three possible arrangements which admit of the carbon atoms forming a closed chain:—

(1) Three pairs of carbon atoms may be doubly-linked, as is assumed to be the case in benzene;

(2) Two pairs may be doubly-linked;

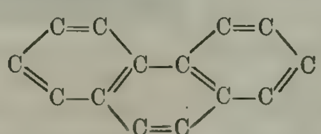
(3) The six atoms may be singly-linked.

There are reasons for representing oil of turpentine and terebene as having two pairs of carbon atoms doubly-linked, and their nucleus formed by a closed chain, which includes these two pairs of atoms. These bodies exhibit no absorption-bands, from which Prof. Hartley concludes that bodies containing a closed chain of carbon atoms, in which only two pairs are doubly-linked, do not cause intermediate absorption. Again, the constitutional formula of camphor may be based on a closed chain of carbon atoms. It is found to be more diactinic than the terpenes, from which it may be inferred that its atoms are less compactly united: a state consistent with the theory of a singly-linked closed chain of atoms. Camphoric acid agrees with camphor in this respect. From the foregoing considerations it is surmised that no molecular arrangement of carbon atoms causes selective absorption, unless three pairs are doubly-linked together in a closed chain.

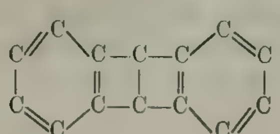
The absorption-spectra of condensed benzene nuclei are next considered.

It was expected, from the generally accepted views as to the constitution of naphthalene and anthracene, that these substances would cause a larger number of absorption-bands than benzene, and that the bands would have greater intensity. A solution of naphthalene, however, of 1 in 60,000 shows four absorption-bands, whereas six bands of benzene, apparent at a dilution of between 1 in 700–800, have been entirely eliminated at 1 in 2500. Therefore, although the number of bands is not increased, the absorptive power is very considerably greater in the case of naphthalene.

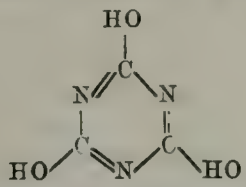
Phenanthren, which is supposed to contain three benzene rings arranged as follows, shows three strong absorption-bands with a solution containing one in 4000:—



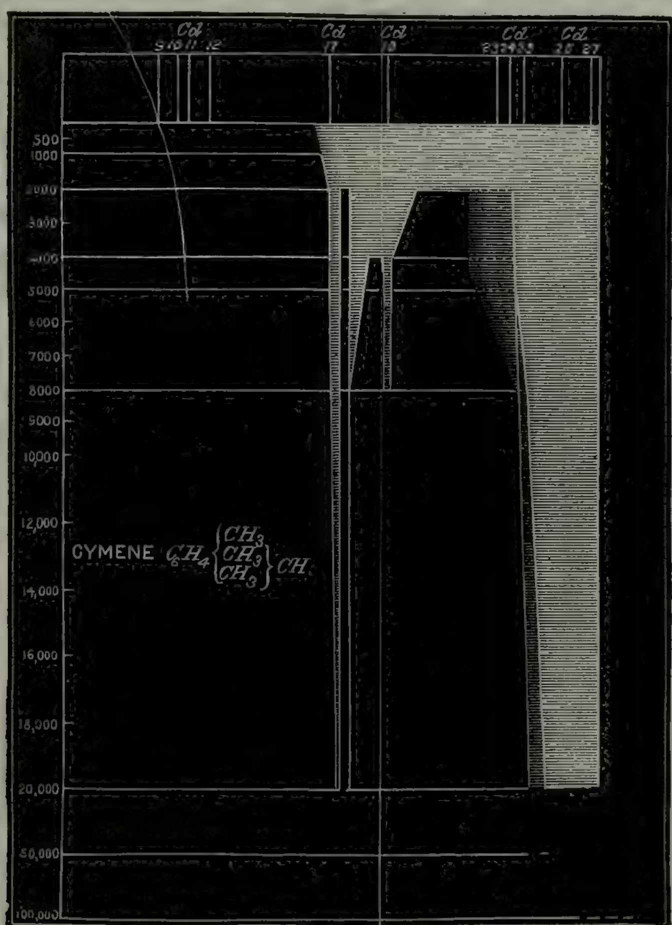
Anthracene,



diluted to 1 in 50 millions with acetic acid still shows considerable absorption. Hydrocyanic is very diactinic; cyanuric acid is not, and Prof. Hartley accordingly assigns to it the formula



It has been shown that cymene has a well-defined absorption-spectrum, and according to Dr. Armstrong this substance forms a part of orange oil, French turpentine, and Russian turpentine. On examining specimens received from Dr. Armstrong, no cymene could be detected in the first two, and less than 4 per cent. in the last. The inference is, therefore, that the cymene found by Dr. Armstrong was formed by the chemical treatment to which these substances were subjected in his investigation.



The wave-length of these cadmium lines is given on p. 299. The light parts indicate the absorbed, and the dark the transmitted, rays.

Although there have been but few workers in this line of research, sufficient has been done to indicate its value in investigating the constitution of colourless bodies.

Report of the Committee, consisting of Mr. F. J. BRAMWELL, Dr. A. W. WILLIAMSON, Professor Sir W. THOMSON, Mr. ST. JOHN VINCENT DAY, Dr. C. W. SIEMENS, Mr. C. W. MERRIFIELD, Dr. NEILSON HANCOCK, Professor ABEL, Captain DOUGLAS GALTON, Mr. NEWMARCH, Mr. E. H. CARBUTT, Mr. MACRORY, Mr. H. TRUEMAN WOOD, Mr. W. H. BARLOW, *and* Mr. A. T. ATCHISON, *appointed for the purpose of watching and reporting to the Council on Patent Legislation.*

THIS Committee begs leave to report that with the exception of the introduction of a Bill on the Patent Law by Mr. Anderson, Mr. Alexander Brown, Mr. Hinde Palmer, and Mr. Broadhurst, which Bill was not proceeded with, there has been, so far as they are aware, no attempt at legislation on the subject. The Committee have spent the five pounds granted to them, and request that they may be reappointed, and that a sum of five pounds be granted to them.

Preliminary Report of the Committee, consisting of Professor LEONE LEVI (*Secretary*), Mr. STEPHEN BOURNE, Mr. BRITTAIN, Dr. NEILSON HANCOCK, Professor JEVONS, *and* Mr. FELLOWS, *appointed for the purpose of inquiring into the present appropriation of wages and sources of income, and considering how far it is consonant with the economic progress of the people of the United Kingdom.*

WHILST the attention of economists and financiers has been directed to ascertain the rate of increase of wealth and capital in the United Kingdom, the corresponding important subject of the mode of its expenditure or the manner of appropriation of wages and other sources of income, has not been subjected to sufficient analysis, nor have its economic bearings been sufficiently appreciated. What proportion of the national income is yearly used as capital, what proportion of capital is devoted to productive or unproductive purposes, how far, in short, is the present method of appropriation consonant with the economic progress of the people of the United Kingdom; these are questions of great moment, worthy of careful attention.

The national income consists of the total amount of utilities produced, less those wasted within the year, from the increment of capital, from land and sea, from industry and manufactures, from commerce and navigation. The total gross receipts of every individual cannot be taken as the total national income. The income of the professional classes, including persons engaged in the general and local government, in the defence of the country, in the learned professions, or in literature, art, and science, and the income of persons engaged in entertaining and performing personal offices for man, as domestic servants, are not independent incomes. Such persons receive what the producers of wealth yearly expend. In like manner, the total gross expenditure of every individual cannot be taken as the sum total of the national expenditure, inasmuch as a large portion

of what is paid away only passes from hand to hand, and is not really expended. What is expended is the amount devoted to the production of the articles consumed, and the amount paid to foreign countries for commodities imported, account being taken of the value of commodities remaining in existence, and for the use of which only a certain percentage should be annually charged. The expenditure for education consists, not in the salaries of teachers and other officers, but in the cost of buildings, and materials used for purposes of instruction, together with the consumption of the staff employed. The expenditure for amusements does not consist in the remuneration of artists, save, as before, the cost of that which they consume, but in the cost of buildings, appliances, and materials. Of the expenditure for alcoholic liquors a large portion remains in the hands of distributors and goes to the State for revenue. Viewed in this light the national balance-sheet will have on the one side the total value of utilities produced, on the other the total amount of expenditure of such utilities, the balance being the surplus left for accumulation, or the amount of loss of national capital.

The national income calculated in money value arises from the following principal sources, viz.:—

Land,	Ironworks,	Railways,	Industry,
Houses,	Quarries,	Canals,	Manufactures,
Mines,	Fisheries,	Shipping,	Commerce,

Receipts for services from foreign countries,
Receipts from foreign and colonial investments, &c., &c.

In all cases the income from these different sources must be estimated by the annual value of products of existing properties, annual value of properties newly produced, and total amount of utilities created by distribution, after all expenses are deducted.

The national expenditure may be distributed as follows:—

State expenditure, viz.: Interest of public debt, civil service, military and naval expenditure, &c.
Local expenditure: Care of the poor, health, roads, &c.
Productive industry for home consumption.
,, ,, export.
Religion, charity, education, science, and art.
Public works of utility, viz.: Railways, canals, &c., &c.
Investments in colonies and foreign countries.

The personal expenditure should be classified as follows:—

Articles of food.
,, drink.
Clothing.
House rent.
Household furniture.
Fire and light.
Education, Church, Charity.
Travelling and amusements.
Domestic service.
Luxuries: Tobacco, ornaments, dogs, and horses.
Taxes.

The data available for the proposed inquiry are doubtless very insufficient, nevertheless much authentic information is available.

As regards income, the Inland Revenue Commissioners supply the annual amount of property assessed to income and property tax. Although

the ascertainment of the total national income is a question apart from the manner in which the different classes of the community participate in the same, the income-tax returns of the amount assessed to each individual under Schedules D & E, and of the aggregate of all the assessments under Schedules A, B, & C, will be found as great helps in the calculation; especially in any attempt to consider the relation of expenditure to income among the different classes of the community. From the reports of the Local Government Board we have the total value of real property subject to local taxation. The Miscellaneous Statistics give the rates of wages in manufactures and trades. From the Agricultural Statistics we have the materials for ascertaining the quantities of agricultural products; from the Board of Trade tables the tonnage of shipping annually built. The Mineral Statistics give the quantities of coal, iron, and other metals produced. As regards Expenditure, the Board of Trade tables give the quantities and values of articles of food and clothing imported and consumed. But no information is given in public documents of the quantities and value of the same produced and consumed at home, and it will have to be obtained from other sources. The Statistics of Coal, the accounts of Water and Gas companies, and the Accounts of the House Tax, supply information regarding the expenditure on house, fire, light, &c. The railway accounts give the amount expended in travelling. Special information would be needed on the expenditure on theatres and amusements; in newspapers, reviews, tracts, and books. And still greater difficulty may be found in estimating the expenditure in articles of consumption, arising from the additional value imparted to such articles by artificial and other circumstances. A large item of national expenditure consists in labour productively or unproductively employed. In its great population the United Kingdom possesses a vast source of wealth, and any portion of the population remaining idle or unproductive must be considered as so much loss of national wealth.

The national income of the United Kingdom is considerable in amount, probably exceeding one thousand millions a year, but its economic value depends on the mode of its appropriation, and any information illustrative of the relation between income and expenditure among the different classes of the community would be of great value. No sharp division, it is true, exists between the upper, middle, and labouring classes; nevertheless there are ample data to assist in the inquiry. Considerable advantage, the Committee thinks, would be derived by the comparison of the personal expenditure in different countries, greatly affected though it is by the difference of temperature and the habits of the people. Are the people of England less thrifty than the people of other countries? Is the amount of national saving in the United Kingdom less than might be expected? Many economic and social problems depend for their solution on the mode in which wages and other sources of income are appropriated, and your Committee ventures to solicit its reappointment with a view of instituting the necessary inquiries, and making a full and exhaustive report on the whole subject.

Report on the present state of knowledge of the application of Quadratures and Interpolation to Actual Data. *By* C. W. MERRIFIELD, *F.R.S.*

I.—INTRODUCTION.

The questions, both of interpolation and quadrature, will be considered, for the purposes of this report, chiefly with reference to the two following cases:—

(*a*) Where a definite number of observations is given, and no intermediate observations are procurable. This is the case with most records of isolated or discontinuous observations, and with time observations.

(*b*) Where a curve is mechanically or graphically given, either actually or implicitly, so that ordinates can be taken at pleasure, while the analytical expression of the curve is either unknown or not available. This is the case with the graphical record of continuous observations, and with the calculation of areas and moments in engineers' work, and in naval architecture.

When any varying quantity, or function, is tabulated, the table gives the value of the function corresponding to certain given values of the subject of the function. The values of the subjects are termed the *arguments* of the table: the corresponding values of the function are termed the *entries*. Interpolation is the problem of finding the value of the entry corresponding to an argument not actually given in the table, but usually intermediate to the extreme arguments. When the form of the function is absolutely unknown, except from the definite values tabulated, interpolation is essentially an indeterminate problem.

When the form of the function is known analytically, and can be used for the purpose of determining the intermediate value or values required, the problem becomes determinate, but the work is then rather that of *computation* than of interpolation. This is equally true whether the computation be direct, and independent of the table, or whether the tabulated values be used to facilitate the computation of those not tabulated. The latter case, under a slight change of aspect, is usually included in the term interpolation—namely, interpolation by means of the known properties of the particular function tabulated. This is not included in the general problem of interpolation, which is the object of this report.

The method of quadratures is usually understood to mean the integration of a function by the use of certain definite values of it. The geometrical expression of this is the quadrature of an area by means of its ordinates. There are two principal and distinct cases of this—one where the function or curve is only known for certain definite values or ordinates, and not intermediately, and the other where the function or curve, although not analytically given, so that the integral calculus can be applied to it directly, is or may be known at any selected point or ordinate whatever. The first case has indeterminateness of the same order as the corresponding problem of interpolation: the second presents itself in the case of curves actually drawn or otherwise continuously indicated, and practically also where the function, although given in analytical form, is not the differential coefficient of a function which can be directly computed;—and this second case has, in itself, nothing indeterminate.

Interpolation has also to be considered with reference to differential coefficients as well as to the function, and also with reference to maxima or minima either of the tabulated function or the argument.

Quadrature also has to be applied to moments as well as to simple integrals. Multiple integrals have also to be considered, but, like simple integrals, always between constant limits. The principal types of these are, in addition to the simple integral,

$$\int_{a_1}^{a_2} y\,dx$$

the moments

$$\int_{a_1}^{a_2} xy\,dx$$

$$\int_{a_1}^{a_2} x^2y\,dx$$

$$\int_{a_1}^{a_2} y^2\,dx$$

$$\int_{a_1}^{a_2} y^3\,dx$$

and multiple integrals of the two types

$$\int_{a_1}^{a_2}\int_{b_1}^{b_2}\int_{c_1}^{c_2} \ldots\ldots u\,dx\,dy\,dz \ldots\ldots$$

and

$$\int_{a^1}^{a^2} \left(\int_{a}^{x}\right)^{n-1} u\,dx^n$$

II.—Interpolation by Known Properties of the Particular Function. Use of Taylor's Theorem.

The calculus of finite differences is of such general and easy application that its use has sometimes superseded other methods which are preferable in particular cases. This is especially true of the ordinary logarithmic tables, including those of circular functions. Where the first difference is constant, or nearly so, it is sufficient to use proportional parts; but when the second and third differences have to be taken into account, it is frequently preferable to use the properties dependent on the form of the function. The advantage of this is very marked in the inverse use of the table, where the argument has to be found from the entry.

The formulæ required may in some cases be obtained by algebraical transformation of the function; but a more general method is afforded by the use of Taylor's theorem in the following form:—

Let $y = \phi x$ be the nearest tabular entry, and let

$$y \pm l = \phi\,(x \pm h)$$

be the interpolation required: l and h, or, often preferably, $\log l$ and $\log h$, have to be determined in terms of one another and of ϕ.

The direct application of Taylor's theorem gives

$$\pm\, l = \pm\, h\,\phi' x + \frac{h^2}{2}\phi'' x \pm \frac{h^3}{6}\phi''' x + \ldots .$$

$$\text{or } l = h.\,\phi' x \left\{1 \pm \frac{h}{2}\frac{\phi'' x}{\phi' x} + \frac{h^2}{6}\frac{\phi''' x}{\phi'' x} \pm \ldots . \right\}$$

whence

$$\log l = \log h + \log \phi' x \pm \frac{mh}{2}\frac{\phi'' x}{\phi' x}$$

$$- \frac{mh^2}{4}\left(\frac{\phi'' x}{\phi' x}\right)^2 + \frac{mh^2}{6}\frac{\phi''' x}{\phi'' x} \quad \text{nearly}$$

where m is the modulus of the logarithms: writing $x = \psi y$, gives similar formulæ for h and $\log h$ in terms of l and ψy. The differential coefficients of ψx may be determined either directly, or by the common formulæ which give $\frac{dx}{dy}$, $\frac{d^2x}{dy^2}$ &c. in terms of $\frac{dy}{dx}$, $\frac{d^2y}{dx^2}$ &c. There is no advantage in setting out the general formulæ, because it is easier to obtain the formula suited to each case by direct differentiation, than by substitution.

In the case of common logarithms, making $\log\,(x \pm h) = \log x \pm k$,

$$\log k = \log\left(\frac{mh}{x}\right) \mp \tfrac{1}{2}\,\frac{mh}{x} \text{ nearly}$$

$$\log h = \log\,(Mxk) \pm \tfrac{1}{2}k \text{ nearly.}$$

Where m is the modulus of common logarithms and M its reciprocal, so that

$$10 + \log m = 9{\cdot}63778\ 43113\ 00537$$

$$\log M = 0{\cdot}36221\ 56886\ 99463.$$

These are far more useful working formulæ for large logarithmic tables than any depending upon differences.*

This process receives an evident simplification when the function tabulated is a simple integral. In that case ϕx is replaced by $\int \chi x dx$, $\phi' x$ by χx, and so on. It is therefore of useful application to the direct tables of elliptic integrals, like Legendre's; but it will not apply to the tables recently printed by the Association, because in these the functions tabulated are not mere integrals, having simple differential coefficients, but are complicated functions, of which the differential coefficients are still more complicated. Nevertheless, whenever $\Delta\phi = \sqrt{(1-\sin^2\theta \sin^2\phi)}$ is known or discoverable, the formulæ of this article may still be of use for interpolating to $F\phi$ and $E\phi$.

These, and other methods of interpolation derived from the properties of the function itself, are of especial advantage at those parts of a table where the rate of change of value of the function differs widely from that of the argument. Immediate examples of this are afforded by the tables of logarithmic sines and tangents for small angles. In these and many similar cases the general methods of interpolation, dependent upon finite differences, are practically useless. It should not be forgotten that there are two kinds of difficulty met with in certain of those cases—one in which a very small change in the argument corresponds to a very great change in the entry, which introduces actual indeterminateness into the attempt to interpolate to the latter—and another where the amounts of change fairly correspond, but, the argument varying uniformly, the rate of change of the entry varies rapidly. Each case has its converse. An example of the former is to be found in the attempt to determine a small angle from its cosine—in which case accuracy is impossible; an example of the second is to be found in the problem of finding the logarithmic sine or tangent of a small angle, in which the only difficulty is the arithmetical one arising out of the particular system of tabulation in common use; that is to say, a difficulty arising from our having selected, for reasons of a general character, a plan of tabulation not suited to the work to be done in the particular case.†

III.—General Considerations Relating to the Application of Finite Differences to Interpolation and Quadrature.

When all that is known of a function is, that it takes certain definite values for corresponding definite values of the independent variable, separated by finite intervals, the function itself, and consequently all its

* A very full account of this method, with copious examples, is given by Legendre under the title 'Méthodes diverses pour faciliter l'Interpolation des grandes Tables trigonométriques' in the *Connaissance des Temps* for 1817, p. 302. The formulæ for logarithms were first given, to one term only, by Dodson, in his 'Antilogarithmic Canon,' dated 1742. The second is also given by Legendre, 'Fonctions Elliptiques,' vol. ii. p. 13. Several other examples will be found in the author's memoir on 'Elliptic and Ultra-elliptic Integrals,' *Phil. Trans.* vol. 152 (1862) pp. 421–427. See also Legendre, *op. cit.* pp. 34, 61, 62.

† The difficulty in the former example is inherent, and therefore insuperable. In the latter example it is met by using a table of natural sines or tangents, and finding the logarithm of the interpolated value, or else by an artifice such as the formation of special tables of $\log \frac{x}{\sin x}$ or of $\log \frac{\tan x}{x}$. These are called Delambre's tables; but they were given long before Delambre's time by John Newton, in his *Trigonometria Britanica* (*sic*) dated 1658; in the folio edition p. 41, § 6.

intermediate values, are simply and absolutely indeterminate. If all that is known of a curve is that it passes through n equidistant points, nothing is really known of the curve. If the points are in a straight line, it may undulate in any manner between them. Nevertheless, it will often be interesting and useful to consider the simplest case, in which the undulations are minimised. Many physical problems are known to contain no undulatory element, and therefore their graphical solution may reasonably be assumed to be the simplest curve, cleared of undulations, which will pass through the points. When these are in a straight line, the solution is obvious. It is not so if they are otherwise distributed. If, for instance, three points in a plane be taken generally, the simplest curve through them, having regard only to its intrinsic qualities, is a circle; but there are many conceivable conditions under which a catenary, or a parabola, might be more probable. The uncertainty appears to be of the same order as the selection of an independent variable. In the practice of experienced draughtsmen, as well as in theory, there is no rule except the general avoidance of discontinuity, and there are not wanting cases in which a local discontinuity is the simplest interpretation. When a base line is assumed, and ordinates are measured with reference to that, it is a question whether the assumption that the second differential is constant is not as good as the assumption that the curvature is so. The question is not very material, except in extreme cases, where the whole process becomes one of bare probability rather than of approximation. In the ordinary application of the calculus of finite differences, the work is good for nothing when any extreme is approached.

The theory of interpolation by means of finite differences appears to be, historically, a mere extension of the rule of 'proportional parts,' namely, that part-way between the arguments corresponds to part-way between the entries—the *part-way* being in each case proportional. This is not exact where one increases or diminishes uniformly, and the other does not; but it was very early noticed that it was approximately true for most tables, and the more nearly true in proportion as the interval between the successive arguments was diminished, the approximation not being in the direct ratio of the diminution of interval, but nearly as the square of that diminution.

Whether few or many orders of differences be taken, the value of the process depends upon the sufficiency of the convergence. If that be secured, the selection of the process is a mere matter of convenience. Without it the process fails.

One of the best examples of this is to be found in the quadrature of a circular segment, by ordinates set off from its chord. The semicircle, however many differences be used, always gives a bad approximation, even if a great number of ordinates be taken. Regarding the question analytically, it appears that the differential coefficients of the ordinate are all infinite at the limits of integration, and the convergence necessarily fails. Geometrically, it is an attempt to represent a curve, which is parallel to its ordinate, by a curve which never can be so within finite range. If, however, instead of taking a semicircle, a smaller segment be taken, there is no theoretical objection to the process; convergency is secured, and practically the requisite approximation is obtained.

The difficulty above indicated has presented itself in the case of a perfectly continuous curve, with everything ascertained, so that exact

ordinates can be obtained by calculation in any way and to any extent that may be demanded. Very different considerations present themselves in dealing with physical data, even when the given abscissæ and ordinates are measured with absolute precision. Here a further assumption of simplicity is required, namely, that there is continuity (in the sense in which that term is used in Cauchy's proof of Taylor's theorem) of the same order as the number of differences used. This does not necessarily exist. In a pressure diagram, for instance, the pressure may, as matter of fact, have varied discontinuously between the selected ordinates, while the assumption of process is, that it has varied continuously.

It is worth while here to mention another problem in which arbitrary processes are often used as if they were definite, and that is, the averaging of discontinuous or irregular phenomena. To fix the ideas, consider the population of a small island represented by the ordinate of a line, the abscissa being proportional to the time. The population line will not be a curve, but a series of steps, falling one unit at every death, and rising at every birth—horizontal between. If the population be large, this will hardly be distinguishable from a curve—probably a continuous one. But if it is endeavoured actually to reduce it to an equivalent continuous curve, this cannot be done with indefinite approximation, unless some further assumption be introduced; for any fair curve lying between one drawn through the top edges of the steps and another through the bottom edges will answer our indefinite question. The general answer is then uncertain to the extent of this difference, at least. Each condition that it is subjected to—as, for instance, equality of areas, of moments, of moments of inertia or the like—merely introduces an equation which must be satisfied by the coefficients of any algebraical formula which may be selected to represent the data.

Some degree of indeterminateness in amount must always remain, unless the conditions are exhausted by assumptions sufficient to render the curve determinate, or by evidence extraneous to the actual data of observation.

This is obvious enough when stated, being merely an extension, from two to more quantities, as well as *in genere*, of the remark, that a mean is indeterminate until we know what mean is meant. Yet it is no uncommon thing to see observations discussed in disregard of this, and treated, not as affording means of determining the parameters of a law assumed, or derived *aliunde*, but as affording the means of determining the law itself with completeness.

The effect of discontinuity increases as we differentiate, and decreases as we integrate. Thus a corner in a curve alters the tangent, or first differential coefficient, discontinuously, and makes the second infinite, while the ordinate only changes its rate of variation, and the change is still less observable on the integral or area. The amount of discontinuity, as well as its order, is to be considered. For many purposes a small discontinuity of low order is of about the same importance as a considerable discontinuity of a higher order of differentiation.

The ordinary assumption, both in interpolation and in quadratures is, that one quantity may be finitely expressed as a rational integral function of the other, with a sufficient approximation, and that the constants of this expression may be determined also with sufficient approximation, from the known values of the quantity assumed to be so expressed as a

function of the other. That is to say, if one quantity be u, and the other x, it is permissible to write

$$u_x = a_0 + a_1x + a_2x^2 + \ldots\ldots a_nx^n$$

when n is the number of intervals, or $n+1$ that of the values of the function: and then to determine the constants, so that the substitution of the $n+1$ values $x = r_0, r_1, r_2 \ldots\ldots$ shall give, for each

$$u_0 = a_o + a_1r_0 + \ldots\ldots a_nr_o^n, \text{ \&c.}$$

There are other equivalent expressions which are sometimes more convenient, for instance:—

$$u_x = (a_0 - x)\,(a_1 - x) \ldots\ldots (a_n - x)$$

Assuming a curve to be generated according to a continuous law, if the equation between the ordinate and the abscissa is of a simpler character, when integrally expressed, than

$$y = a_0 + a_1x + \ldots\ldots + a_nx^n$$

that will be shown by the *as* with a high suffix vanishing, or, if finite differences be used, by the higher differences vanishing. It follows that, if the ordinates are known to be exact, a form may in general be assumed, not less simple than the above—that is to say, of a degree only one less than the number of ordinates—and any simplification will appear from the resulting equations. If, however, the law is in reality more complex, the assumption made is only good as an approximation. Whether it be an approximation or not, hinges upon the question of convergence.

It will be shown further on that, as regards quadrature, the rules run in pairs, $2m-1$ equidistant ordinates giving a result of the same order of accuracy as $2m$ ordinates, and generally a rather better result arithmetically. This is proved as far as 7 ordinates, and is a probable inference generally. Assuming convergency, the higher rules would seem to be better for the same number of ordinates than the lower. That is to say, the rule of 9 ordinates or 8 intervals is better than the rule of 5 intervals or 4 ordinates, taken as $4 + 4$, and this again better than the rule of 3 ordinates or 2 intervals taken as $2 + 2 + 2 + 2$; while this again is better than the polygonal rule taken as 8×1.* The main part of the foregoing reasoning is independent of any supposition as to the equidistance of the ordinates. But it does imply that the ordinates are exactly given. If this be untrue, it is not easy to see how much probability is involved in our assumption. Apparently this question is indeterminate, like that of the best mean, where the object of the mean is not stated. Mr. George Darwin has shown † that, for the quadrature of an area of which the ordinates are liable to uncertainty, the broken line simply joining the heads of the ordinates gives a more probable area than that obtained by any of the higher parabolas.

It may be worth while to remark, that, for the purposes of interpolation, the relation of ordinate and abscissa is a supposition of mere convenience, not of necessity. The only necessary relation is that of function and variable.

* It is more convenient to compare the number of intervals into which the base is divided, than the number of ordinates. The arithmetical comparison always turn upon the intervals.

† See *The Messenger of Mathematics* for January, 1877.

With quadrature, it is rather different. The ordinary formulæ of quadratures presuppose the relation of ordinate and abscissa, and any variation of this supposition, such as a transformation to polar co-ordinates, requires a corresponding change in the formula.

In connecting integration, regarded as the inverse of differentiation, with integration viewed as the limit of summation, the fundamental assumption is continuity, and that in a very restricted and special sense. Its applications to interpolations and quadratures also presuppose convergence, and unless both continuity and convergence are secured, any arithmetical conclusions drawn from our processes must fail for want of evidence of their application, when strictly considered. For rough practical purposes, a great many processes are useful in ordinary cases, which will not bear carrying to extremes.

IV.—Theorems of Finite Differences.

Section 1.—Common formulæ of direct interpolation and quadrature by ordinary differences.

If $u_0, u_1, u_2, \ldots\ldots u_n$ be any $n+1$ consecutive series of numbers or homologous quantities whatever, and if we *difference* them so that $u_{r+1} - u_r = \Delta u_r$, it is well known, and can be easily proved by induction, that the operative symbol Δ is subject to the ordinary laws of algebraical combination, and that, provided the subject of operation does not alter, it may be treated as an algebraical constant. Moreover, since a consequence of this is

$$u_{r+1} = (1+\Delta) \,.\, u_r$$

the suffixes also follow the index law, and

$$u_{r+q} = (1+\Delta)^q . u_r$$

The only limitations are that q and r shall be positive and integral, and that $r+q$ shall not exceed n. With these limitations, the expansion is identically verified. So far, no assumption is needed concerning equidistant variations.

The theory of finite differences assumes that $u_0, u_1 \ldots\ldots u_n$ are successive states of a function of a variable increasing by equal increments, so that if $u_0 = \phi z$, and if h be the increment of x, $u_r = \phi\,(z+rh)$. Then by mere induction we obtain

$$\phi\,(z+nh) = \phi z + n\,\Delta.\phi z + \frac{n\,(n-1)}{1\,.\,2}\Delta^2\,.\,\phi z + \frac{n\,(n-1)\,(n-2)}{1\,.\,2\,.\,3}\Delta^3.\phi z + \ldots\ldots *$$

This, with a slight difference of notation only, is Brook Taylor's theorem in finite differences, which would now be expressed symbolically by

$$\phi\,(z+nh) = (1+\Delta)^n\,.\,\phi z$$

Then, making the further assumptions of continuity and convergence, in exactly the same way as the expansion of ϵ^x is deduced as the limit of the binomial expansion $\left(1+\frac{x}{r}\right)^r$ when r is made infinite, Taylor deduced

* It is worth while to compare this with the corresponding geometrical expression given by Newton (*Principia*, Book III. Prop. xl. Lemma 5, Case 1, 3rd ed. 1726, p. 486).

the differential theorem of expansion which usually bears his name, and which may be symbolically written as

$$\phi(x+h) = \varepsilon^{h\frac{d}{dx}} . \phi(x).$$

It is worth while to notice the two points: that he obtained it as a limit, and that he obtained it indirectly, the assumptions of continuity and convergence being tacit.* Taylor does not proceed to discuss these points, which, however, are now well known to all who have read Cauchy's observations on the theorem.

The full consequences of Taylor's two theorems appear to have been first stated by Arbogast† in the symbolical form—

$$\mathrm{F}(1+\Delta) . u = \mathrm{F}\varepsilon^{h\frac{d}{dx}} . u‡$$

When F is any function whatever, but is applied to the symbols of operation only, viz., Δ and $h\dfrac{d}{dx}$, and the resulting operation applied to u.

Subject to suitable interpretation in the case of negative and fractional values, this formula really includes the whole of the ordinary theory of interpolation and quadratures.

As regards fractional interpretation, since $(1+\Delta)^r . u_0 = u_r$, a fractional index applied to $(1+\Delta)$ simply means an interpolated value. In the same way a negative index applied to $(1+\Delta)$ merely means a preceding value.

A fractional index applied to Δ has no useful meaning at all, being indeterminate §; a negative index also, strictly speaking, gives indeterminateness, which, however, is removable, within limits. For we have to interpret Δ^{-1} so that $\Delta . \Delta^{-1} u_r = u_r$. This is satisfied if Δ^{-1} represents the indefinite series ending with $\ldots\ldots u_{r-2} + u_{r-1}$, and the use of this between limits gets rid of the indeterminateness. A more exact and intelligible statement of this is that Δ^{-1}, standing by itself, is either indeterminate or infinite; but $\Delta^{-1}u_r - \Delta^{-1}u_q$ is perfectly determinate, and stands for

$$u_q + u_{q+1} + \ldots\ldots u_{r-2} + u_{r-1}.$$

In this respect Δ^{-1} is strictly comparable with $\int dx$, and, in fact, we have

* See the *Methodus Incrementorum directa et inversa, auctore* Brook Taylor, LL.D. . . . London, 1716.

† See his *Calcul des Dérivations*, Strasburg, 1800, pp. 343–352. See particularly § 405, p. 351, Formula E.

‡ It is worth while, following Arbogast, to distinguish this theorem from that underwritten, in which F affects the whole expression that follows it:—

$$\mathrm{F}\left\{(1+\Delta)\times\phi x\right\} = \epsilon^{mh\frac{d}{dx}} . \mathrm{F}\phi x = (1+\Delta)^m \times \mathrm{F}\phi x.$$

A little consideration will show that this is but another way of writing the identity

$$\mathrm{F}\left\{\phi(x+mh)\right\} = \mathrm{F}\phi(x+mh)$$

This is an important theorem, but a very different one, and it has no immediate application to the object of this report.

§ This is in fact a question of general interpolation. If the value of a function is only known for integral values of n, there is no means of distinguishing

$$\mathrm{F}x \text{ from } \mathrm{F}x + \phi(\sin n r\pi) . fx$$

which are wholly different when r is fractional. This is but one example of a very general truth.

indeterminately: $\left(h\frac{d}{dx}\right)^{-1}u = \frac{1}{h}\int udx = \frac{1}{\log(1+\Delta)}\cdot u$

$$= \Delta^{-1}\left(1+\frac{1}{2}\Delta-\frac{1}{12}\Delta^2+\frac{1}{24}\Delta^3-\ldots\ldots\right)u;$$

determinately: $\frac{1}{h}\int_{qh}^{rh} udx = \Delta^{-1}u_r - \Delta^{-1}u_q$

$$+\frac{1}{2}(u_r-u_q)$$

$$-\frac{1}{12}(\Delta u_r - \Delta u_q)$$

$$+\frac{1}{24}(\Delta^2 u_r - \Delta^2 u_q) - \ldots\ldots$$

the first form, $\Delta^{-1}u_r - \Delta^{-1}u_q$ having the value already stated, namely,

$$u_q + u_{q+1} + \ldots\ldots \; u_{r-2} + u_{r-1}$$

and u taking the values u_r and u_q at the limit rh and qh.

The coefficients here used are called the coefficients of quadrature; they are the coefficients of the expansion *

$$\frac{x}{\log(1+x)} = 1 + V_1x + V_2x^2 + V_3x^3 + \ldots\ldots$$

$$V_1 = \frac{1}{2} \qquad V_2 = -\frac{1}{12}$$

$$V_3 = \frac{1}{24} \qquad V_4 = -\frac{19}{720}$$

$$V_5 = \frac{3}{160} \qquad V_6 = -\frac{863}{60480}$$

$$V_7 = \frac{275}{24192} \qquad V_8 = -\frac{33953}{3628800}$$

$$V_9 = \frac{8183}{1036800}$$

This is the leading theorem of simple quadratures, all the other theorems being mere transformations or extensions of it. Before it can be advantageously applied, some transformation is needed, because both sets of differences run diagonally in the same direction, so that the required differences cannot be got without the use of ordinates beyond the limits of the integration. The simplest transformation is that by ascending differences, which is easily obtained by expanding in terms of $F = \frac{\Delta}{1+\Delta}$ instead of $\Delta = \frac{F}{1-F}$. But the most useful process is to expand partly by ascending and partly by descending differences, whereby we obtain symmetry, and use ordinates falling entirely within the limits of integration. Observe that $(1+\Delta)(1-F) = 1$.

* See De Morgan *Diff. and Int. Calc.* p. 262; *Lacroix*, vol. iii. p. 182. Also Woolhouse *On Interpolation, &c.* (London, Layton, 1865), reprinted from the *Assurance Magazine*, vol. xi.

$$\therefore \frac{1}{h}\int dx = 1 : \log(1+\Delta) = -1 : \log(1-\mathrm{F})$$
$$= \mathrm{F}^{-1} - \mathrm{V}_1 + \mathrm{V}_2\mathrm{F} - \mathrm{V}_3\mathrm{F}^2 + \ldots\ldots$$
$$= 1 + \Delta^{-1} - \mathrm{V}_1 + \mathrm{V}_2\mathrm{F} - \mathrm{V}_3\mathrm{F}^2 + \ldots\ldots$$

Now introduce the limits of integration, using ascending differences at one end and descending at the other. This gives

$$\frac{1}{h}\int_{x_0}^{x_n} y dx = y_n + \Delta^{-1} y_n - \mathrm{V}_1 y_n + \mathrm{V}_2 \mathrm{F} y_n - \ldots.$$
$$-(\Delta^{-1} y_0 + \mathrm{V}_1 y_0 + \mathrm{V}_2 \Delta y_0 + \ldots.)$$
$$= \tfrac{1}{2} y_0 + y_1 + y_2 + \ldots\ldots + y_{2-1} + \tfrac{1}{2} y_n$$
$$- \mathrm{V}_2(\Delta y_0 - \mathrm{F} y_n) - \mathrm{V}_3(\Delta^2 y_0 + \mathrm{F}^2 y_n) \ldots.$$
$$= \mathrm{V}_{r+1}\left\{\Delta^r y_0 + (-)^r \mathrm{F}_r y_n\right\} - \ldots\ldots$$

or, since $\mathrm{F}_r y_n = \Delta^r (1+\Delta)^{-r} . y_n = \Delta^r y_{n-r}$,

we have, finally,

$$\frac{1}{h}\int_{x_0}^{x_n} y\, dx = \tfrac{1}{2} y_0 + y_1 + y_2 + \ldots\ldots + y_{n-1} + \tfrac{1}{2} y_n$$
$$- \mathrm{V}_2(\Delta y_0 - \Delta y_{n-1}) - \mathrm{V}_3(\Delta^2 y_0 + \Delta^2 y_{n-2}) - \ldots\ldots$$
$$- \mathrm{V}_{r+1}\left\{\Delta_r y_0 + (-)^r \Delta^r y_{n-r}\right\} \ldots\ldots$$

which is the usual formula of quadratures.*

Section 2.—Inverse Interpolation.

Using the common formula of direct interpolation, the problem is to find the value of n from the formula

$$\phi_n = \phi_0 + n\Delta\phi_0 + \frac{n.n-1}{1.2}\Delta^2\phi_0 + \ldots\ldots$$

where everything but n is known.

Stopping at any given order (say the r^{th}) of differences, neglecting all beyond it, which is evidently permissible provided the differences be convergent, and sufficiently so (and only on that hypothesis) this really involves the solution of an equation of the r^{th} degree in n. It is usual to effect the solution by successive approximation, that is to say, by stopping successively at the first, second, third, &c., differences in succession, and determining at each step a new and more accurate value of n.

Thus, neglecting all beyond the first difference, a first approximation gives

$$n_1 = (\phi_n - \phi_0) : \Delta\phi_0.$$

This merely amounts to the use of proportionate parts.

The second step is to calculate

$$\tfrac{1}{2}(n_1 - 1)\Delta^2\phi_0 = c_1,$$

* See De Morgan, *Diff. and Int. Calc.* p. 313. The proof there given is substantially the same as this, only differing in arrangement. The above arrangement perhaps shows a little more obviously the reason why the constant part used is the same in both formulæ. Stated more exactly, what is done is to introduce an intermediate (but indefinite) limit, and to reverse one of the definite integrations.

then, neglecting all further terms, as a second approximation

$$n_2 = (\phi_n - \phi_0) : (\Delta \phi_0 + c_1).$$

For a third approximation

$$\tfrac{1}{2}(n_2 - 1) \left\{ \Delta^2\phi_0 + \tfrac{1}{3}(n - 2)\Delta^3\phi_0 \right\} = c_2$$

may be calculated: this gives

$$n_3 = (\phi_n - \phi_0) : (\Delta \phi_0 + c_2).$$

The process is very cumbrous when carried beyond the first correction of the proportional part. But it has one very marked advantage, namely, that, being a tentative process, any error in one step is more or less completely corrected at the next step, and the practical effect of accidental error is thus to make the approximation less rapid, instead of absolutely vitiating the result. It might even happen that an error of calculation, by being nearer the required answer, might give a more rapid approximation.

The rapidity of approximation depends, firstly, upon the degree of convergence; and, secondly, upon the first approximation being sufficiently near the required result. This is exactly parallel to what takes place in the numerical solution of equations, and there is, here as there, the same difficulty presenting itself where any given approximation is nearly halfway between two solutions, and the successive results oscillate between the two, instead of converging to either.*

When convergence is assured, this tentative method is probably the best, and is at any rate the safest. An extension of Hutton's rule for extracting roots † might possibly be found of use. But the criterion of convergence in this process has not been satisfactorily determined. There is, however, reason for believing that the convergence is not so good as in the direct tentative process given above.

This process is applicable, not only to the common formula of interpolation by descending differences, but to all formulæ which can be arranged by ascending powers or factorials of n, the index of interpolation For in any such form it still remains as the approximate solution with respect to x of an equation of the form

$$y = a_1 x + a_2 x^2 + a_3 x^3 + \ldots\ldots$$

where x^m is either a power or a factorial of x.

Section 3.—Equidistant Ordinates, not differenced.

In general, writing

$$u_x = c_0 u_0 + c_1 u_1 + \ldots\ldots c_n u_n$$

where $u_0\, u_1 \ldots\ldots$ are certain given values of u corresponding to given values of x, namely, x_0, $x_1 \ldots\ldots x_n$, and then assuming a form of u in terms of x which will allow the coefficient c to be so determined that $x = x_r$ shall make $c_r = 1$ (when x_r is one of the given values) and all the other c's vanish, a formula of interpolation is obtained which can be converted into a formula of quadrature by integrating with regard to x from

* See Horner, in *Leybourn's Repository*, No. 19, p. 63, and J. R. Young, *Theory and Solution of the Higher Equations*, second edition (1843) *note*, pp. 474–6.

† For which see the *London, Edin. and Dublin Philos. Mag.* vol. xx. (1860) p. 446, and the *Philos. Trans.* for 1862, vol. clii. pp. 429–431.

0 to n. When the values are equidistant, $r\,h$ or $r\,\Delta\,x$ must be used instead of x_r.

There is usually an advantage, both in the symmetry of the formulæ and in the probability of an accurate result, in taking ordinates on both sides of the origin of interpolation. On any reasonable hypothesis, a mean result is generally better than one near an extreme, and this remark is verified by the greater tendency to convergence of the formulæ when the interpolated value lies near the origin of interpolation than when it lies away from it. As a general rule, where extreme accuracy is required, it should not lie farther off than half the equidistant interval. There are then two kinds of symmetry to consider: symmetry to a central ordinate, involving an odd number of ordinates and an even number of intervals; and symmetry to an interval, involving an even number of ordinates and an odd number of intervals.

Taking the former case, of symmetry to an ordinate, we may write for the ordinates

$$u_{-n} \ldots\ldots u_{-2}, u_{-1}, u_0, u_1, u_2 \ldots\ldots u_n,$$

and the general formula of interpolation will be given by

$$u_x = c_{-n} u_{-n} + \ldots\ldots\ldots c_{-1} u_{-1} + c_0 u_0 + \ldots\ldots + c_n u_n,$$

where the coefficients c are functions of x, determined by the condition that $x = rh$ shall make $c_r = 1$, and all the others vanish. The simplest way in which this can be done rationally and integrally is by writing

$$u_x = \frac{x(h^2 - x^2)(4h^2 - x^2)\ldots\ldots(n^2h^2 - x^2)}{\lfloor 2n \,.\, h^{2n}} \times$$
$$\left\{ \frac{v_n u_0}{x} - \frac{v_{n-1} u_1}{x-h} - \frac{v_{n-1} u_{-1}}{x+h} + \ldots\ldots \right.$$
$$\left. \pm \frac{u_n}{x - nh} \pm \frac{u_{-n}}{x + nh} \right\}^*$$

where v_r is the coefficient of x^r in the binomial expansion $(1 + x)^{2n}$.

This gives for

$n = 0$, $u_x = u_0$ (as it ought)

$$n = 1,\ u_x = \frac{x(h^2 - x^2)}{2h^2} \left\{ \frac{2u_0}{x} - \frac{u_1}{x-h} - \frac{u_{-1}}{x+h} \right\}$$

$$n = 2,\ u_x = \frac{x(h^2 - x^2)(4h^2 - x^2)}{24h^4} \left\{ \frac{6u_0}{x} - \frac{4u_1}{x-h} - \frac{4u_{-1}}{x+h} + \right.$$
$$\left. \frac{u_2}{x-2h} - \frac{u_{-2}}{x+2h} \right\}$$

In the second case, of symmetry to an interval, let any even number of ordinates be

$$N, M, \ldots . B, A, A_1, B_1, \ldots\ldots M_1, N_1$$

and let the variable $x = \frac{1}{2} z$, or x be the independent variable measured from the middle point of the middle interval $A\,A_1 = h = 2k$. Then if v^r

* Boole writes this in a slightly different form; see his *Finite Differences* 2nd edition, p. 50. The formulæ themselves are due to Newton; see his *Methodus Differentialis* (London, 1711, published by W. Jones as part of the *Analysis per quantitatum series, fluxiones*, &c.) pp. 93–101. They are also to be found in vol. i. of Horsley's edition of Newton's works.

be the coefficient of x^r in the binomial expansion of $(1+x)^{2n-1}$, the corresponding formula is

$$u_x = \frac{(k^2 - z^2)(9k^2 - z^2) \ldots\ldots\ldots (2_{n-1})^2 k^2 - z^2}{2 \,.\, 4 \,.\, 6 \ldots\ldots\ldots (4n-2)\; k^{4n-3}}$$

$$\left\{ \frac{v_n A}{k+z} + \frac{v_n A_1}{k-z} - \frac{v_{n-1} B}{3k-z} - \frac{v_{n-1} B_1}{3k+z} + \right.$$

$$\left. \ldots\ldots \pm \frac{N}{(2n-1)k - z} \pm \frac{N_1}{(2n-1)k+z} \right\}^*$$

Thus if $n=1$

$$u_x = \tfrac{1}{2}\frac{k-z}{k}A + \tfrac{1}{2}\frac{k+z}{k}A_1$$

$$\left.\begin{array}{l} = A_1 \text{ when } z = +k \\ = A \text{ when } z = -k \end{array}\right\} \text{(as it ought).}$$

This formula gives a very important theorem for the bisection of an interval. Making $z=0$, k divides out, and there remains

$$u_0 = \frac{1^2 . 3^2 . 5^2 \ldots\ldots (2n-1)^2}{2 . 4 . 6 \ldots\ldots (4n-2)} \left\{ v_n (A + A_1) - \right.$$

$$\left. \frac{1}{3} v_{n-1} (B + B_1) + \frac{1}{5} v_{n-2} (C + C_1) - \ldots\ldots \right\}$$

When $n = 1, 2u_0 = A + A_1$

$n = 2, 16u_0 = 9(A + A_1) - (B + B_1)$

$n = 3, 256u_0 = 150(A + A_1) - 25(B + B_1) + 3(C + C_1)$.

The general case of $n=1$ is simply equivalent to the use of proportional parts.

Although, as has been already remarked, the rules for quadrature by ordinates can be obtained by integrating the corresponding expressions for interpolation by ordinates, that is not the easiest way of obtaining them. One way is to integrate $\int_0^n (1+\Delta)^x \, dx$ after expanding it, and then, rejecting all the terms after Δ^r, make $n = r$ and substitute $E - 1$ for Δ. This process is given in most of the text books.†

But a simpler and more symmetrical method, and one which can easily be extended to higher integrals, is by the use of indeterminate multipliers, as follows: Write $u = a_0 + a_2 x^2 + a_4 x^4 + a_6 x^6 + \ldots\ldots$ whence

$$\frac{1}{2}\int_{-n}^{n} u\,dx = n a_0 + \frac{1}{3}n^3 a_2 + \frac{1}{5}n^5 a_4 + \frac{1}{7}n^7 a_6 + \ldots\ldots$$

Again substituting $0, \pm 1, \pm 2, \pm 3 \ldots\ldots$ in succession for x,

$$u_0 = a_0$$

$$\frac{1}{2}(u_{-1} + u_1) = a_0 + a_2 + a_4 + a_6 + \ldots\ldots\ldots$$

* See De Morgan, *Diff. and Int. Calc.* p. 549.

† See Boole, *Finite Differences*, art. 10; also Murray's *Shipbuilding*, p. 32.

$$\frac{1}{2}(u_{-2} + u_2) = a_0 + 2^2a_2 + 2^4a_4 + 2^6a_6 + \ldots\ldots\ldots$$

$$\frac{1}{2}(u_{-3} + u_3) = a_0 + 3^2a_2 + 3^4a_4 + 3^6a_6 + \ldots\ldots\ldots$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad = \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$

Now, introducing indeterminate multipliers,

$$\frac{1}{2}\lambda_0 + \lambda_1 + \lambda_2 + \lambda_3 + \ldots\ldots\ldots \lambda_n = n$$

$$\lambda_1 + 2^2\lambda_2 + 3^2\lambda_3 + \ldots\ldots n^2\lambda_n = \frac{1}{3}n^3$$

$$\lambda_1 + 2^4\lambda_2 + 3^4\lambda_3 + \ldots\ldots n^4\lambda_n = \frac{1}{5}n^5$$

$$\lambda_1 + 2^6\lambda_2 + 3^6\lambda_3 + \ldots\ldots n^6\lambda_n = \frac{1}{7}n^7$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot = \cdot \cdot \cdot \cdot$$

from which the value of any λ is easily formed, by means of determinants if necessary. For any given value of n the coefficients are those of the corresponding rule for $2\,n$ ordinates or $2n + 1$ intervals. Thus, stopping at $n = 1$

$$\frac{1}{2}\lambda_0 + \lambda_1 = 1, \lambda_1 = \frac{1}{3} \therefore \lambda_0 = \frac{4}{3}$$

$$\int_{-1}^{1} u dx = \frac{1}{3}(u_{-1} + 4u_0 + u_1)$$

Again, stopping at $n = 2$

$$\frac{1}{2}\lambda_0 + \lambda_1 + \lambda_2 = 2, \lambda_1 + 4\lambda_2 = \frac{8}{3}, \lambda_1 + 16\lambda_2 = \frac{32}{5}$$

$$\text{whence } \lambda_2 = \frac{14}{45}, \lambda_1 = \frac{64}{45}, \lambda_0 = \frac{24}{45}$$

$$\int_{-2}^{2} u dx = \frac{2}{45}(7u_{-2} + 32u_{-1} + 12u_0 - 32u_1 + 7u_2).$$

The rules for an odd number of intervals or an even number of ordinates may be got by giving x the successive values $\pm 1, \pm 3, \pm 5 \ldots\ldots$ Then $u_{-n} + u_n$ takes the same value as before. Writing $n = 2\,m + 1$, and using as indeterminate multipliers $\mu_1, \mu_3, \mu_5 \ldots\ldots$ the equations become

$$\mu_1 + \mu_3 + \quad \mu_5 + \ldots\ldots\ldots \mu_{2m+1} = 2\,m + 1$$

$$\mu_1 + 3^2\mu_3 + 5^2\mu_5 + \ldots\ldots\ldots (2\,m + 1)^2\mu_{2m+1} = \frac{1}{3}(2\,m + 1)^3$$

$$\mu_1 + 3^4\mu_3 + 5^4\mu_5 + \ldots\ldots\ldots (2\,m + 1)^4\mu_{2m+1} = \frac{1}{5}(2\,m + 1)^5$$

$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot = \cdot \quad \cdot \quad \cdot$$

Stopping at $m = 0$, $\mu_1 = 1$

$$\int_{-1}^{1} u dx = \frac{1}{2}(u_{-1} + u_1)$$

Stopping at $m = 1$, $2m + 1 = 3$

$$\mu_1 + \mu_3 = 3,\ \mu_1 + 9\mu_3 = 9$$

$$\therefore \mu_3 = \frac{3}{4},\ \mu_1 = \frac{9}{4}, \text{ and}$$

$$\int_{-3}^{3} u\,dx = \frac{3}{4}(u_{-3} + 3u_{-1} + 3u_1 + u_3)$$

It is to be observed that the interval in the μ formula is 2, and not unity.

The actual coefficients for quadrature by means of equidistant ordinates, when the interval is taken as unity, are *

2 ordinates or 1 interval	$\frac{1}{2}(1 + 1)$	The trapezoidal rule
3 ordinates or 2 intervals	$\frac{1}{3}(1 + 4 + 1)$	The parabolic rule, or Simpson's first rule
4 ordinates or 3 intervals	$\frac{3}{8}(1 + 3 + 3 + 1)$	Simpson's second rule
5 ordinates or 4 intervals	$\frac{2}{45}(7 + 32 + 12 + 32 + 7)$	
6 ordinates or 5 intervals	$\frac{5}{288}(19 + 75 + 50 + 50 + 75 + 19)$	
7 ordinates or 6 intervals	$\frac{1}{140}(41 + 216 + 27 + 272 + 27 + 216 + 41)$	
8 ordinates or 7 intervals	$\frac{7}{17280}(751 + 3577 + 1323 + 2989 + 2989 + 1323 + 3577 + 751)$	
9 ordinates or 8 intervals	$\frac{4}{14175}(989 + 5888 - 928 + 10496 - 4540 + 10496 - 928 + 5888 + 989)$	
10 ordinates or 9 intervals	$\frac{9}{89600}(2857 + 15741 + 1080 + 19344 + 5778 + 5778 + 19344 + 1080 + 15741 + 2857)$	
11 ordinates or 10 intervals	$\frac{10}{598752}(16067 + 106300 - 48525 + 272400 - 260550 + 427368 - 260550 + 272400 - 48525 + 106300 + 16067)$	

In the foregoing the numerical coefficients only are given, and the ordinates have to be inserted. Thus, the ordinates being a, b, c, d, e, the rule for five ordinates or four intervals is

$$\frac{2}{45}(7a + 32b + 12c + 32d + 7e) \times \text{interval}.$$

To the above should be added Weddle's approximate rule for 7 ordinates, or 6 intervals, namely:

$$\frac{3}{10}(1 + 5 + 1 + 6 + 1 + 5 + 1).$$

* These are all taken from Cotes, *Harmonia Mensurarum*, by Robert Smith, Cambridge, 1722, *De Methodo Differentiali*, p. 33. The principle of these rules seems to have been known to Newton; see his *Methodus Differentialis* already quoted.

This is a modification of the rule of seven ordinates already given, differing from it only by $\frac{1}{140}\Delta^6$.*

It will be observed that these formulæ are symmetrical *end for end*, and since the integration is between definite limits, the origin of the abscissæ is indeterminate, and may be taken so as to fall in the middle, or so that the equivalent integration is from $-rh$ to $+rh$. It follows that, for the purposes of comparison, instead of taking

$$y = b_0 + b_1 x + b_2 x^2 + \dots\dots\dots b_n x^n$$

we may take, since

$$\int_{-1}^{+1} x^{2m-1}\,dx = 0 \text{ always}$$

$$y = b_0 + b_2 x^2 + \dots\dots\dots b_{m2} x^{2m}$$

omitting the terms containing odd powers of x; and that we therefore obtain no greater generality by using $2\,m$ ordinates instead of $2\,m-1$. The error in either way is of the same order.†

The formulæ of quadrature for an odd number of ordinates or an even number of intervals appear to have been also given by James Stirling,‡ who adds a set of what he calls corrections. The number of ordinates being $2\,m-1$, the correction is of the form

$$-\mathrm{A}\,\mathrm{E}^{-m}(\mathrm{E}-1)^{2m} \times \text{base}$$

the coefficient A being apparently determined so as to make the corrected value exactly agree with the result obtained from integration, when both are applied to x^{2m}. But they do not lead to the next rule, for $2\,m+1$ ordinates. As a particular example, the correction for the rule of three ordinates, namely, $\frac{\text{base}}{6}(u_{-1}+4u_0+u_1) \times$ base, is $-\frac{\text{base}}{180}(u_{-2}-4u_{-1} + 6u_0 - 4u_1 + u_2) \times$ base. The values of the coefficients A are inexactly given by Stirling as

$$\frac{1}{180}, \frac{1}{470}, \frac{1}{930}, \frac{1}{1600}$$

$$\text{instead of} \quad \frac{1}{180}, \frac{2}{945}, \frac{3}{2800}, \frac{296}{467775}$$

The inaccuracy is not a mistake, because Stirling only uses them as a test of approximation, and not as a means of obtaining accuracy.

Bertrand (*Calcul Intégral*) gives the corrections in a slightly different form, from which the coefficients just given are obtainable by multiplying Bertrand's corresponding coefficient by $2^{2m} : \Delta^{2m}0^{2m}$. In the following table we give Bertrand's first coefficient only. It is the excess of the com-

* The first eight formulæ are given by Thomas Simpson and verified by Atwood. All the rules are given (but with some misprints) by Bertrand (*Calcul Intégral*). Atwood makes a curious mistake in the rule of 8 ordinates. He is endeavouring to correct Simpson, with whom, however, his result is really identical, only that Atwood has introduced the factor 49 into both numerator and determinator, without seeing that it divides out: see *A Disquisition on the Stability of Ships*, by George Atwood, F.R.S., read before the Royal Society, March 8, 1798, and reprinted separately (p. 62 of reprint).

† See Todhunter, *On the Functions of Laplace, &c.* pp. 98 and 104.

‡ See his *Methodus Differentialis*, London, 1730, p. 146, Prop. xxxi. He stops at nine ordinates.

putation by the rule for $2m-1$, or $2m$ ordinates, over the actual value of the integral $\int_0^1 x^{2m}dx$.

Number of ordinates	Number of intervals	Excess	Number of ordinates	Number of intervals	Excess
2	1	$\frac{1}{6}$	7	6	$\frac{1}{38880}$
3	2	$\frac{1}{120}$	8	7	$\frac{167}{10588410}$
4	3	$\frac{1}{270}$	9	8	$\frac{37}{17301504}$
5	4	$\frac{1}{2688}$	10	9	$\frac{865}{631351908}$
6	5	$\frac{11}{52500}$	11	10	$\frac{260927}{136500000000}$

This is a fair indication of the error to be expected in treating a convergent form by these rules. It is no criterion where the curve approaches parallelism to the ordinate.

It must be remembered also that the higher rules use more ordinates, and therefore ought to give more accuracy. As regards relative accuracy, the proper test is so to use the rules as to cut up the function or curved area into the same number of intervals, for which purpose it is necessary to use the least common multiple of the order of (or number of intervals in) the rules. Thus, what has hitherto been considered, in the case of two and three intervals, is the comparison of

$$\frac{1}{6}\left\{1\cdot\phi(0)+4\phi\left(\frac{1}{2}\right)+1.\phi(1)\right\}$$

$$\text{with } \frac{1}{8}\left\{1\ \phi(0)+3\phi\left(\frac{1}{3}\right)+3\phi\left(\frac{2}{3}\right)+1.\phi(1)\right\}$$

the proposed comparison is between

$$\frac{1}{3}\left(1+4+2+4+2+4+1\right)$$

$$\text{and}\quad \frac{3}{8}\left(1+3+3+2+3+3+1\right)$$

with corresponding ordinates, namely

$$\phi(0),\ \phi\left(\frac{1}{6}\right),\ \phi\left(\frac{2}{6}\right)\ \ldots\ldots\ \phi(1)$$

In this way, using 21 ordinates, or 20 intervals,

$$\int_{-10}^{+10} x^6dx \text{ gives}$$

		Errors
Accurate value by integration . .	$2,857,142\frac{6}{7}$	
By rule of 5 ordinates . . .	$2,857,173\frac{1}{3}$	$+\ 30\frac{10}{21}$
By rule of 6 ordinates . . .	$2,857,208\frac{1}{3}$	$+\ 65\frac{10}{21}$

Ratio of errors 128 : 275

$$\text{Again,} \int_0^{20} x^6 dx \text{ gives}$$

Accurate value by integration . .	$182{,}857{,}142\frac{6}{7}$	Errors
By rule of 5 ordinates	$182{,}857{,}173\frac{1}{3}$	$+\ 30\frac{10}{21}$
By rule of 6 ordinates . . .	$182{,}857{,}208\frac{1}{3}$	$+\ 65\frac{10}{21}$

which accords with the former result.

In the same way, using 7 ordinates or 6 intervals, we find that

$$\int_{-3}^{+3} x^4 dx \text{ gives}$$

Accurate value by integration	97·2	Errors
By rule of 3 ordinates	98	+ 0·8
By rule of 4 ordinates	99	+ 1·8

Ratio of error 4 : 9

$$\text{Again,} \int_0^6 x^4 dx \text{ gives}$$

Accurate value by integration . . .	1555·2	Errors
By rule of 3 ordinates	1556	+ 0·8
By rule of 4 ordinates	1557	+ 1·8

which accords with the former result. These coincidences arise from the change of origin not affecting the definite integration.

In this particular case the errors may be shown symbolically by operating at once upon $\left(1 + \Delta\right)^x$ from $x = 0$ to $x = 6$ by

(1) Simpson's first rule (three ordinates)
(2) Simpson's second rule (four ordinates)
(3) The rule of 7 ordinates

The results are, in ascending powers of Δ

$$(1) \quad \ldots\ldots \quad 6 + 18 + 27 + 24 + 12\frac{1}{3} + 3\frac{1}{3} + \frac{1}{3}$$

$$(2) \quad \ldots\ldots \quad 6 + 18 + 27 + 24 + 12\frac{3}{8} + 3\frac{3}{8} + \frac{3}{8}$$

$$(3) \quad \ldots\ldots \quad 6 + 18 + 27 + 24 + 12\frac{3}{10} + 3\frac{3}{10} + \frac{41}{140}$$

and the errors are

$$\text{for (1)} \quad + \frac{1}{30}\Delta^4 + \frac{1}{30}\Delta^5 + \frac{17}{420}\Delta^6$$

$$\text{for (2)} \quad + \frac{3}{40}\Delta^4 + \frac{3}{40}\Delta^5 + \frac{23}{280}\Delta^6$$

Neglecting the last term, it appears that the ratio of error is as 4 : 9 in favour of Simpson's first rule as against the second.

It is worth while to continue this comparison backwards. For thus it is not necessary to have recourse to arithmetic. Taking a parabola with axis parallel to the ordinates, it is easily seen that the rectangle between the middle ordinate and the base is a better approximation than the trapezium consisting of the chord, the base, and the extreme ordinates, and that the ratio of the errors is + 1 : − 2, the errors being of opposite sign.

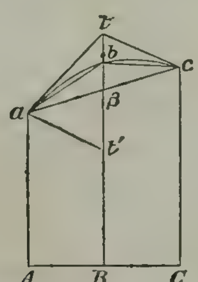
So far as the first six cases go, therefore, it appears that a rule with

an even number of ordinates has an error numerically about double that of the corresponding rule for one ordinate less. The number of cases tried is not sufficient to warrant any general inference as to the comparative amount of error, especially when we consider their signs; but it is highly probable that the rule with an odd number of ordinates is always better arithmetically than, and not only of the same order of error as, the rule with one more ordinate. As has already been stated, no general investigation of these comparative values appears to have been made. The point is, however, one rather of analytical curiosity than of real importance. The rules requiring high orders of differences are better replaced by lower rules with more ordinates, unless in the very rare cases where the ordinates themselves are difficult to calculate. It is claimed that such an exception is found in calculating the curve of stability of a ship when the mainwale, or armour shelf, and the deck are successively immersed; but there is at least a doubt in these cases whether the discontinuity, which makes the calculation of more ordinates difficult, does not vitiate the accuracy of the higher orders of differences. If that be so, the advantage sought by their use—namely, to be sure of not adding an error of calculation to the errors of measurement, or to the errors due to wide intervals—would of course be lost. Nevertheless the higher rules are analytically nearer the truth, and must be actually so in certain cases. Only it must not be taken for granted that these are usual cases. It is the practice of French naval architects to use the polygonal rule throughout their calculations, in deliberate preference to the rule of three ordinates. The arithmetical work is thereby much simplified, and so the liability to accidental error is diminished. Moreover by taking ordinates sufficiently close, the error of the rule can be reduced without limit, and where the ordinates are inexact, it is not clear that the parabolic rule has any advantage.*

In dealing with actual data, the use of a large number of ordinates has evidently the advantage of taking a more complete account of the facts than the use of a smaller number. Any want of continuity between the ordinates is necessarily ignored by all the rules, and that to the greater extent, the greater the interval.

The rule of nine ordinates, and many of the higher rules, involve negative as well as positive coefficients, and are inconvenient on that account.

The amount of the difference between the use of the polygonal rule and the parabolic (or Simpson's first) rule is best shown geometrically as follows:



* Dr. Farr has used the same rule, or an arithmetical process equivalent to it, for the integrations used in the Life Tables calculated under his superintendence by the Registrar-General's Department. See the *Sixth*, *Eleventh*, and *Twelfth Reports of the Registrar-General for Births, Deaths, and Marriages in England* (1847, 1852, 1853), and the English Life Table published by the Registrar-General.

Let Aa, Bb, Cc be three consecutive equidistant ordinates. Then, by the polygonal rule, the area is represented by the trapeziums AabB and BbcC. Let at, tc be tangents at the extremities of the curve, and draw $a\,t'$ parallel to tc. Then the actual area of the curve regarded as a common parabola is the trapezium AacC *plus* $\frac{2}{3}$ of the triangle $a\,t\,c$ $(= t\,a\,t')$ while the polygonal area A a b c C is A a c C $+ \frac{1}{2}\,a\,t\,c$ $=$ A $a\,c$ C $+ \frac{1}{2}\,t\,a\,t'$, and the difference between these is $\left(\frac{2}{3} - \frac{1}{2}\right) t\,a\,t'$ $= \frac{1}{6}\,t\,a\,t'$.

When more ordinates are used, it is easy, by repeating the construction, to form a triangle which shall give a superior limit to the error made by substituting the trapezoidal rule for the parabolic. For the geometrical addition of the curvilinear segments, taking each as two-thirds of its circumscribing triangle corresponds very nearly (although not exactly) to an algebraical addition which can be effected graphically on the second ordinate from each end, by drawing parallels to the chords and tangents from the head of the first ordinates.* It also follows that if the tangents at the extremities of the curve are parallel, the difference between the two rules disappears, and they lead to a result practically identical— that is to say, only differing by an error of a high order.

Section 4.—Multiple integrals, ordinates not differenced.

A multiple integral of the form $\int_{-a}^{a}\int_{-b}^{b}$ . . . . . $u\;dx\;dy$, in which the limits are all constant, and the variables (except u) all independent, can be computed by treating each variable separately, by a repeated application of any process of arithmetical integration. In the case of a double integral applied to the calculation of volume this is equivalent to cutting the volume by parallel plane sections, obtaining the areas of these by any method of ordinates, and then summing the areas of these sections, each taken as an ordinate, to obtain the volume. Thus, taking nine equidistant ordinates with the interval h in one direction, and k in another at right angles to it, and calling them

$$\begin{matrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{matrix}$$

an application of Simpson's rule gives us for the plane areas

$$\frac{1}{3}h\,(a_1 + 4b_1 + c_1),\ \frac{1}{3}\,h\,(a_2 + 4b_2 + c_2),\ \frac{1}{3}\,k\,(a_3 + 4b_3 + c_3)$$

or, using the vertical sets,

$$\frac{1}{3}\,k\,(a_1 + 4a_2 + a_3),\ \frac{1}{3}\,k\,(b_1 + 4b_2 + b_3),\ \frac{1}{3}\,k\,(c_1 + 4c_2 + c_3)$$

* See Woolhouse 'On Interpolation, &c.' *Assurance Magazine*, vol. xi. p. 308—separately published by C. and E. Layton in 1865. See also Leclert, 'Note sur le Calcul numérique des aires curvilignes planes,' *Annales du Génie civil*, tome viii. p. 630. M. Leclert states that his note is in great part a reproduction of M. Béech's lessons.

A second application of the rules to either set gives

$$\frac{1}{9}hk\left\{\begin{array}{c} a_1 + \ \ 4b_1 + \ c_1 \\ + 4a_2 + 16b_2 + 4c_2 \\ + a_3 + \ \ 4b_3 + \ c_3 \end{array}\right\} = \mathrm{V}$$

It might be supposed that this represented the volume-integral of a paraboloid with its axis parallel to the ordinates; but this is not so, for in the paraboloid, since all parallel sections are equal and similar,

$$a_1 - 2b_1 + c_1 = a_2 - 2b_2 + a_2 = a_3 - 2b_3 + c_3$$

$$\text{or} \left\{\begin{array}{c} a_1 - 2b_1 + \ c_1 \\ -2a_2 + 4b_2 - 2c_2 \\ + a_3 - 2b_2 + \ c_3 \end{array}\right\} = 0$$

Combining this with V (above) gives

$$\mathrm{V} = \frac{2}{3}hk\left\{\begin{array}{ccc} 0 & b_1 + 0 & \\ + a_2 + 2b_2 + c_2 & & \\ + 0 & b_3 + 0 & \end{array}\right\}^* = \frac{1}{3}hk\left\{\begin{array}{c} a_1 + \ 0 \ + c_1 \\ 0 \ + 8b_2 + 0 \\ a_3 + \ 0 \ + c_3 \end{array}\right\}$$

So that the volume of the paraboloid for nine ordinates is given by either set of five symmetrical ordinates only: that is to say, by either the central one and those at the four corners, or by the central one and the four at the middle points of the sides of the square.

Dr. Woolley, to whom this simplification is due, showed that this rule applied not only to one paraboloid through the heads of the nine ordinates, but to the sum of the volumes of two paraboloids in two ways, either

$$\left\{\begin{array}{lll} a_1 & & \\ a_2 & b_2 & \\ a_3 & b_3 & c_3 \end{array}\right\} + \left\{\begin{array}{lll} a_1 & b_1 & c_1 \\ & b_2 & c_2 \\ & & c_3 \end{array}\right\}$$

or

$$\left\{\begin{array}{lll} a_1 & b_1 & c_1 \\ a_2 & b_2 & \\ a_3 & & \end{array}\right\} + \left\{\begin{array}{lll} & & c_1 \\ & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{array}\right\}$$

In fact, let b_2 be taken for origin, $a_2\, b_2\, c_2$ for the axis of x, and $b_1\, b_2\, b_3$ for the axis of y, z being normal to the plane of the paper, then writing the equation to a paraboloid as

$$z = a + bx + cy + dx^2 + ey^2 + fxy + ax^3 + \beta x^2y + \gamma xy^2 + \delta y^3$$

and integrating first with regard to y between the limits $\pm\frac{k}{h}x$, and then with regard to x between the limits 0 and h, the volume whose base is the triangle $c_1\, b_2\, c_3$ is expressed by

$$ahk + \frac{2}{3}bh^2k + \frac{1}{2}dh^3k + \frac{1}{6}ehk^3 + \frac{2}{5}ah^4k + \frac{2}{15}\gamma h^3k^2.$$

The other three components may be obtained by interchanging h and k, and other corresponding letters, and then by changing the signs of h and k.

The altitudes of the nine points are obtained by writing 0 and $\pm h$ for

* See the *Mechanic's Magazine* for 5th April, 1851, vol. 54, p. 265; also *Murray's Shipbuilding*, pp. 35–6. See also *Inst. Nav. Arch.* vol. vi. (1865), p. 44, and vol. viii. (1867) p. 210.

x and 0, and $\pm k$ for y. Making these substitutions, the volume of the whole solid is found to be

$$V = \frac{2}{3} hk\,(6a + 2dh^2 + 2ek^2)$$
$$= \frac{2}{3} hk\,(a_2 + b_1 + 2b_2 + b_3 + c_2)$$
$$= \frac{1}{3} hk\,(a_1 + a_3 + 8b_2 + c_3 + c_1).$$

If, moreover, the paraboloid be reduced to one of the second degree by making $\alpha\beta\gamma\delta$ vanish, the following equations also hold:—

$$\text{vol. on } a_1\,c_1\,c_3 = \frac{2}{3} hk\,(b_1 + b_2 + c_2) = \frac{2}{3} hk\,(2b_2 + c_1) - \frac{2}{3} fh^2k^2$$
$$\text{vol. on } c_1\,a_1\,a_3 = \frac{2}{3} hk\,(a_2 + b_2 + b_1) = \frac{2}{3} hk\,(2b_2 + a_1) + \frac{2}{3} fh^2k^2$$
$$\text{vol. on } a_1\,a_3\,c_3 = \frac{2}{3} hk\,(a_2 + b_2 + b_3) = \frac{2}{3} hk\,(2b_2 + a_3) - \frac{2}{3} fh^2k^2$$
$$\text{vol. on } c_1\,c_3\,a_3 = \frac{2}{3} hk\,(b_3 + b_2 + c_2) = \frac{2}{3} hk\,(2b_2 + c_3) + \frac{2}{3} fh^2k^2$$

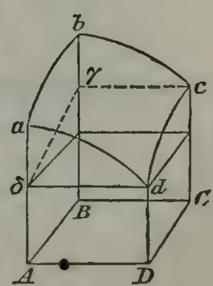
The rule for the corner ordinates is not very convenient. The other rule, when we have nine ordinates only, may be written, having regard to the coefficients alone, as

010
121
010

For a considerable number, say 5×11, it becomes

01010101010
12222222221
02020202020
12222222221
01010101010

The rule for the coefficients is that all the ordinates which are odd in both planes of section have the coefficient zero: all the others have the coefficient 2, except the border rows and columns, where the coefficient is 1 instead of 2. The summation, governed by these coefficients, has then to be multiplied by $\frac{2}{3} hk$.



A geometrical proof is easily given, as follows. Let $abcd$ be a portion of the paraboloid corresponding to the rectangular base ABCD, and let the planes of section be supposed (in the first instance) parallel to principal planes. It is a well-known property of the paraboloid that its sections by any series of planes parallel to one another and to the axis, are similar and equal parabolas. Project the arc cd orthogonally on the plane ABba by a cylinder passing through $cd\delta\gamma$. It is plain that the solid ABCD$d\delta\gamma c$ is this parabolic cylinder *plus* a solid rectangle. All the sections of the outlying solid $abcd\delta\gamma$, parallel to BCcb, are equal and similar portions of equal parabolas, and therefore its volume is the same as that of a cylinder, having the parabolic segment $cb\gamma$ for

its base, and AB for its altitude. Hence the volume of the paraboloid between the extremities of nine ordinates, $a_1 \ldots\ldots c_3$, resolves itself into $2kx$, the parabolic area whose ordinates are $a_2\ b_2\ c_2$, added to $2h \times$ the parabolic area whose ordinates are

$$b_1 - b_2,\ b_2 - b_2\ (=0),\ b_3 - b_2$$

or, by the rule for parabolic areas,

$$V = 2k\frac{h}{3}(a_2 + 4b_2 + c_2) + 2h\frac{k}{3}\left\{(b_1 - b_2) + 4(b_2 - b_2) + (b_3 - b_2\right\}$$
$$= \frac{2}{3}hk\ (a_2 + b_1 + 2b_2 + b_3 + c_2)$$

The restriction as to the direction of the principal planes is equivalent to writing $F = 0$ in the general equation of the paraboloid

$$Z = A + Bx + Cy + Dx^2 + Ey^2 + Fxy$$

but $\Sigma\ (x \pm p)\ (x \pm q) = 4\,xy$ identically, and $(x + p)\ (x + q) - xy$ is the variation of any ordinate (p, q) from the middle one, as regards this term alone; it is therefore evident that, for the symmetrical integral, the effect of this term vanishes.

Two applications of the polygonal rule are easily seen to be equivalent to drawing a hyperbolic paraboloid through the heads of every four ordinates, the four right lines joining the ordinates two and two being the generators (of both systems). The last paragraph shows that its volume-integral can be expressed by interpolating a middle ordinate, and using that only, instead of the four others. This appears to be equivalent to the reduction obtained by Woolley's rule in the degree above; but it is of no practical use, seeing that it only substitutes the sum of $(m-1)\ (n-1)$ ordinates for that of mn ordinates, an advantage which, in general, is no compensation for the interpolation.

Two applications of the polygonal rule lead to the scheme of multipliers :—

$$hk\left\{\begin{array}{ccccccccc}
\frac{1}{4} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{4} \\
\frac{1}{2} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & \frac{1}{2} \\
\frac{1}{2} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & \frac{1}{2} \\
\frac{1}{2} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & \frac{1}{2} \\
\frac{1}{4} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{4}
\end{array}\right\}$$

on comparing this with Woolley's multipliers

$$\frac{4}{3}hk\left\{\begin{array}{ccccccccc}
0 & \frac{1}{2} & 0 & \frac{1}{2} & 0 & \frac{1}{2} & 0 & \frac{1}{2} & 0 \\
\frac{1}{2} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & \frac{1}{2} \\
0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\
\frac{1}{2} & 1 & 1 & 1 & 1 & 1 & 1 & 1 & \frac{1}{2} \\
0 & \frac{1}{2} & 0 & \frac{1}{2} & 0 & \frac{1}{2} & 0 & \frac{1}{2} & 0
\end{array}\right\}$$

it is to be observed that, while the first is less accurate on the supposition that the surface is of strictly parabolic character, and convergent, yet it has the advantage of taking account of the surface (using the above example) at 45 points instead of 30. It thus secures that the surface to which the arithmetical summation refers shall coincide with the surface to be measured in 45 points as against 30, on the assumption of accurate measurements. The advantage of the higher rule, therefore, depends upon there being no possibility of a periodic term, and upon there being no such want of convergence as would render terms of higher degree than $x^3 y^3$ noticeable. If the ordinates are inexact, this advantage of the polygonal rule holds *à fortiori.*

The author has shown* that there exists a similar reduction in the number of ordinates necessary for the summation of a triple integral. Writing the 27 ordinates of

$$\begin{aligned} u = {} & a_0 + a_1 x + \beta_1 y + \gamma_1 z \\ & + a_2 x^2 + \beta_2 y^2 + \gamma_2 z^2 + \lambda yz + \mu zx + \nu xy \\ & + a_3 x^3 + \beta_3 y^3 + \gamma_3 z^3 \\ & + (\lambda_1 z + \lambda_2 y)\, yz + (\mu_1 x + \mu_2 z)\, zx \\ & \qquad + (\nu_2 x + \nu_1 y)\, xy \end{aligned}$$

as

$$\begin{matrix} a_1\ b_1\ c_1 & a_1'\ b_1'\ c_1' & a_1''\ b_1''\ c_1'' \\ a_2\ b_2\ c_2 & a_2'\ b_2'\ c_2' & a_2''\ b_2''\ c_2'' \\ a_3\ b_3\ c_3 & a_3'\ b_3'\ c_3' & a_3''\ b_3''\ c_3'' \end{matrix}$$

the treble integral $\int_{-h}^{h}\int_{-k}^{k}\int_{-l} h\, dx\, dy\, dz$ is expressed by

$$\frac{4}{3} hkl\, (b_2 + b_1' + a_2' + c_2' + b_3' + b_2'')$$

in which the absolute middle ordinate does not appear. In fact, arranging the 27 letters which represent the ordinates in a cube, the only ones which appear are the middle ordinates of faces. The late Professor Rankine expressed this rule in the following form: 'The mean density of a parallelopiped is the mean of the densities at the middle points of its six faces.' This supposes the density to be a parabolic function of the three co-ordinates, not higher than the third degree, and thus, of course, excludes the case (which usually presents itself physically) of the density varying from the middle to the bounding surface. This rule, like Woolley's, may be modified by using corner ordinates, or the ordinates corresponding to the middle points of the edges: only then the formulæ are less simple, and the middle ordinate of all does not disappear.

All the remarks about Woolley's rule inadequately representing the surface, as compared with the polygonal rule, apply *à fortiori* to this. Whatever may be the convergence, except upon a certain limited hypothesis, namely, that the function is of definite parabolic form, coincidence between the actual subject of integration, and the subject of summation, is secured at too few points for the results to be reliable.

It had been observed by the author that there was a peculiar relation of the ordinates in these rules, namely,

* See Scott Russell's *Modern Naval Architecture,* vol. i. p. 127, and *Trans. I. N. A.* vol. vi. (1865) p. 47.

1. Simple measurement $x = \frac{1}{6}\,(6a)$

2. Simpson's rule $\int y\,dx = \frac{1}{3}\,h\,(a + 4b + c)$

3. Woolley's rule $\iint z\,dx\,dy = \frac{2}{3}\,hk\,(a_2 + b_1 + 2b_2 + b_3 + c_2)$

4. Merrifield's $\iiint y\,dx\,dy\,dz = \frac{4}{3}\,hkl\,(a_2' + b_2 + b_1' + b_3' + b_2'' + c_2')$

or, as the multipliers may be graphically arranged,

$$\begin{array}{cccc} & & 1 & 1\,1 \\ 6\,; & 1\,4\,1\,; & 1\,2\,1\,; & 1\,0\,1\,; \\ & & 1 & 1\,1 \end{array}$$

there being a curious tendency of the middle ordinate to 'move out.' The late H. J. Purkiss, by operating upon the equivalent form

$$u_0 = u_0 + Ax^2 + By^2 + Cz^2 + \ldots .$$
$$(n \text{ variables})^*$$

showed that the n^m integral

$$V = \int_{-h}^{h}\int_{-k}^{k}\int_{-l}^{l} \ldots\ldots u\,dx\,dy\,dz \ldots\ldots$$

was represented by

$$V = \frac{1}{3}\,2^{n-1}\,hkl \ldots . \left\{\Sigma - 2\,(n-3)\,u_0\right\}$$

when $u_0 = f\,(0{,}0{,}0 \ldots .)$ and

$$\begin{aligned} \Sigma = & f\,(h{,}0{,}0 \ldots .) + f\,(-h{,}0{,}0 \ldots .) \\ & + f\,(0{,}k{,}0 \ldots .) + f\,(0{,}k - k{,}0 \ldots .) \\ & + f\,(0{,}0{,}l \ldots .) + f\,(0{,}0{,}-l{,} \ldots .) \\ & + \&c. \end{aligned}$$

Multiple integrals of the form

$$\iiint \ldots .\; u\,(dx)^m = U_m$$

may be treated by rules nearly similar to those already given for simple integrals. It is worth while to observe that in this form of integral only one integration (the last) is between definite limits, the others being rather algebraical forms expressed by the notation of the integral calculus, than actual integrations. Thus $\iint u\,dx^2$ between the limits $\pm n$ is not the analogue of $\int_{-h}^{h}\int_{-k}^{k} u\,dx\,dy$, where h and k are each made $= n$, but is an abbreviated expression for $\int_{-n}^{n} dx \int_{o}^{x} u\,dx$. This becomes evident, when it is remembered that U_m is simply the solution of $\frac{d^m U_m}{dx^m} = u$. Moreover, after one integral has been taken between limits, all following integrals are mere multiples, with a parabolic series added, on account of

* See *Trans. I. N. A.*, vol. vi. for 1865, p. 48.

the constants of integration. These constants must not be forgotten, but as they disappear when the origin of integration is suitably taken, they need not be further discussed here.

The same treatment which was applied to the investigation of Cotes's formulæ may also be applied to a double integral, only then it is necessary to use a series with odd powers only, because the even powers disappear for $\pm$ limits. Writing

$$u = a_1 x + a_3 x^3 + a_5 x^5 + \dots\dots\dots$$

and taking the integral between limits $\pm n$

$$\frac{1}{2}\,\mathrm{U}_n = cn + \frac{1}{2\,.\,3}\,a_1 n^3 + \frac{1}{4\,.\,5}\,a_3 n^5 + \frac{1}{5\,.\,6} a_3 n^7 + \dots\dots\dots$$

Assuming the first integral to vanish with x, c vanishes, and the first significant term is $\frac{1}{6}\,a_1 n^3$. Now writing in succession

$$\pm 1,\ \pm 3,\ \pm 5 \dots\dots \text{ for } x.$$

$$\frac{1}{2}(-u_{-1} + u_1) = a_1 + a_3 + a_5 + \dots\dots$$

$$\frac{1}{2}(-u_{-3} + u_3) = 3a_1 + 3^3 a_3 + 3^5 a_5 + \dots\dots$$

$$\frac{1}{2}(-u_{-5} + u_5) = 5a_2 + 5^3 a_3 + 5^5 a_5 + \dots\dots \text{ \&c.}$$

or, using indeterminate multipliers

$$\lambda_1 + 3\lambda_2 + 5\lambda_3 + \dots\dots \quad n\lambda_n = \frac{1}{2\,.\,3}\,n^3$$

$$\lambda_1 + 3^3\lambda_2 + 5^3\lambda_3 + \dots\dots n^3\lambda_n = \frac{1}{4\,.\,5}\,n^5$$

$$\lambda_1 + 3^5\lambda_2 + 5^5\lambda_3 + \dots\dots n^5\lambda_n = \frac{1}{6\,.\,7}\,n^7 \text{ \&c.}$$

. . . .

$$\text{stopping at } n = 1,\ \lambda_1 = \frac{1}{6}$$

$$\text{stopping at } n = 3,\ \lambda_1 = \frac{567}{160},\ \lambda_2 = \frac{51}{160}$$

that is to say,

$$\iint u\,dx^2 \text{ between limits } \pm h \text{ is}$$

$$\frac{1}{3}\,h^2\,(-u_{-1} + u_1)$$

$$\iint u\,dx^2 \text{ between limits } \pm 3h \text{ is}$$

$$\frac{3}{80}\,h^2\,(-17u_{-3} - 189u_{-1} + 189u_1 + 17u_3)$$

Similar formulæ, symmetrical to an ordinate instead of to an interval, would be obtained by writing $0, \pm 1, \pm 2 \dots\dots$ for x. But the integral vanishes for $x = 0$, and these formulæ would evidently be less advantageous than those of the odd series, for the same reason that in a simple integral the even series is the better.

These formulæ are, however, rather curious than useful. For the treatment of multiple integrals, symmetrical differences are more convenient.

Section 5.—Quadrature by differential coefficients.

The reciprocal of the formula

$$\Delta = \varepsilon^{h\frac{d}{dx}} - 1$$

enables the difference between a definite integral and the term of a series of ordinates to be expressed by means of the successive differential coefficients for values corresponding to the extreme values of the function. Calling these u_0 and u_n

$$\Delta^{-1} u_{nh} - \Delta^{-1} u_0 = \left\{ \varepsilon^{h\frac{d}{dx}} - 1 \right\}^{-1} \left\{ u_n - u_0 \right\},$$

There is nothing indeterminate about this equation, the left-hand side of which is the sum

$$u_0 + u_1 + u_2 + \ldots\ldots + u_{n-1}$$

while the right-hand side has for its first term $\frac{1}{h}\int_0^{nh} u\,dx$, for its second term $-\frac{1}{2}(u_n - u_0)$ and for its general term thereafter,

$$\frac{(-)^r}{1\,.\,2\,.\,3\,\ldots\ldots\,2r+2} \mathrm{B}_{2r+1}\, h^{2r+1} \left\{ \frac{d^{2r+1}}{dx^{2r+1}} u_n - \frac{d^{2r+1}}{dx^{2r+1}} u_0 \right\}$$

where B_{2r+1} represents Bernoulli's numbers taken without regard to sign.

The complete formula in its usual form is

$$h \left\{ \frac{1}{2} u_0 + u_1 + u_2 + \ldots\ldots + u_{n-1} + \frac{1}{2} u_n \right\}$$

$$= \int_0^{nh} u\,dx + \frac{1}{6}\,\frac{h^2}{\underline{|2}}(u'_n - u'_0) - \frac{1}{30}\,\frac{h''}{4}\,(u'''_n - u'''_0)$$

$$+ \ldots . + (-)^r \mathrm{B}_{2r+1} \frac{h^{2r+2}}{\underline{|2r+2}} \left(\frac{d^{2r+1}}{dx^{2r+1}} u_n - \frac{d^{2r+1}}{dx^{2r+1}} u_0 \right)$$

$$+ \ldots .$$

The meaning to be attached to $\frac{d^r u_n}{dx^r}$ and $\frac{d^r u_0}{dx^r}$ is that they are the values of $\frac{d^r u}{dx^r}$ when x is made severally equal to nh and to zero.*

The use of this formula presents no difficulty except in one remarkable case, pointed out by Legendre,† in which all the odd differential coefficients after some particular value of r take the same value at both limits. Among these may be instanced $u = \sqrt{(1 - k^2 \sin {}^2 x)}$, the limits being 0 and $\frac{1}{2}\pi$ or π. All the odd differential coefficients are affected with the factor $\sin x \cos x$, which vanishes at both limits, so that each term of the expansion contains zero as a factor. Nevertheless,

* See Woolhouse *On Interpolation, Summation, &c.*, part ii. p. 45 (note), for a very singular extension of this formula.

† See his *Fonctions Elliptiques*, vol. ii. p. 57

the summation is not identical with the complete elliptic integral, as may easily be ascertained upon trial—and there are many other functions which present the same peculiarity. The paradox seems the greater, inasmuch as the numerical coefficients of the differential forms are highly convergent, seeing that when r is large

$$\frac{B_{2r+1}}{\lfloor 2r+2} : \frac{B_{2r-1}}{\lfloor 2r} = 1 : 4\pi^2 \doteq 1 : 40 \text{ nearly.}$$

The explanation, however, is, that the numerical coefficients introduced by the differentiation performed upon u increase without limit, so that $\frac{d^{2r+1}}{dx^{2r+1}}(u_n - u_0)$ becomes really $\infty - \infty$, which is necessarily indeterminate, and may (and usually will) exceed the corresponding factor in the previous term in some ratio which is a multiple of r^2, and which increases without limit as r increases. Then the series finally becomes divergent, and the paradox is solved.

In many such cases, and notably so in the rectification of the quarter-ellipse, the subdivision of the base, that is to say, an increase in the number of ordinates, gives extremely rapid convergence towards the true value. Thus for $k = \sin 45^\circ$, if we take three ordinates only, viz.,

$$\begin{array}{ll} x = 0 & u_1 = 1 \\ x = 45^\circ & u_2 = \sin 60^\circ = 0{\cdot}8660254 \\ x = 90^\circ & u_3 = \sin 45^\circ = 0{\cdot}7071068 \end{array}$$

$$\begin{aligned} \tfrac{1}{2}u_1 &= 0{\cdot}5 \\ u_2 &= 0{\cdot}8660254 \\ \tfrac{1}{2}u_3 &= 0{\cdot}3535534 \\ \hline &\ 1{\cdot}7195788 \end{aligned}$$

This, multiplied by $\frac{1}{4}\pi$, gives for the length of the quarter ellipse 1·350284. The value taken from Legendre's table is 1·3506438820.

If we were to use the parabolic rule we should have

$$\begin{aligned} u_1 &= 1{\cdot} \\ 4u_2 &= 3{\cdot}4641016 \\ u_3 &= 0{\cdot}7071068 \\ 3\ \lfloor &\ 5{\cdot}1712084 \\ &\ 1{\cdot}7237361 \end{aligned}$$

This, multiplied by $\frac{1}{4}\pi$, gives 1·35382, which is not so good a result as we got before. The anomaly here is the counterpart to the one already mentioned. Its explanation is, that if the ordinates are differenced, the differences diverge at once, and, therefore, the series of which Cotes' rules are a mere transformation is divergent from the beginning, so that the more terms of it are taken, the farther from the truth is the result. In other words, the higher rules are worse, instead of better, than the polygonal rule. This is an instructive example of the advantage of a subdivided interval over a rule of a higher order.

Section 6.—Interpolation of direction: maxima and minima.

It frequently happens that it is required to find, by means of given ordinates, whether differenced or not, the value of some particular differential co-efficient, or else the value of the variable corresponding to some given value of the differential coefficient. These ultimately depend upon the symbolic equation

$$h\frac{d}{dx} = \log.\,(1+\Delta)$$

suitably transformed and duly interpreted, or solved. In certain cases, the desired result may be obtained by mere algebraical transformation, by indeterminate coefficients or otherwise.

As an example, let it be required to obtain a formula for the tangent at the head of the middle ordinate of the set

$$u_0\ u_1\ u_2\ u_3\ u_4$$

the common interval being h. The analytical problem is to determine

$$\frac{du_2}{dx} = h\,(1+\Delta)^2 \log.\,(1+\Delta)\,u_0$$

in such a form as to stop the difference series at $\Delta^4 u_0$. The work is

$$h\frac{du_2}{dx} = (1+\Delta)^2\left(\Delta - \frac{1}{2}\Delta^2 + \frac{1}{3}\Delta^3 - \frac{1}{4}\Delta^4\right)u_0$$

$$= \left(\Delta + \frac{3}{2}\Delta^2 + \frac{1}{3}\Delta^3 - \frac{1}{12}\Delta^4\right)u_0$$

$$= \left(\frac{1}{12} - \frac{2}{3}\mathrm{E} + \frac{2}{3}\mathrm{E}^2 - \frac{1}{12}\mathrm{E}^4\right)u_0$$

$$= \frac{2}{3}(u_3 - u_1) - \frac{1}{12}(u_4 - u_0).$$

The process is perfectly general, and needs no further remark, except that the work might have been made a little more symmetrical by taking the middle ordinates as origin. This will give considerable simplification in the algebraical solution. To obtain this,

$$\text{write } u = ax + cx^3$$

omitting the even powers, which evidently disappear in the result.

$$\text{Then } \frac{du_0}{dx} = a + 3cx^2\ (= a \text{ when } x = 0)$$

$$u_1 = -u_{-1} = \frac{1}{2}(u_1 - u_{-1}) = ah + ch^3$$

$$u_2 = -u_{-2} = \frac{1}{2}(u_2 - u_{-2}) = 2ah + 8ch^3$$

and λ_1 and λ_2 are to be so determined that

$$\lambda_1(u_1 - u_{-1}) + \lambda_2(u_2 - u_{-2}) = ah$$

$$\text{This gives } 2\lambda_1 + 4\lambda_2 = 1,\ 2\lambda_1 + 16\lambda_2 = 0$$

whence $\lambda_1 = \frac{2}{3}$, $\lambda_2 = -\frac{1}{12}$. This, allowing for the change of origin, is the same result as that already obtained.

The general problem of maxima and minima is, in interpolation as in ordinary analysis, to determine u and x so as to make $\frac{du}{dx} = 0$. It is a particular case of the more general problem in which $\frac{du}{dx} = a$, but it is practically much simplified by the consideration that Δu is generally very small when $\frac{du}{dx}$ vanishes, so that the approximate position of the maximum or minimum is visible at sight; but there is no such help in the general case.

The process for determining a maximum or minimum is to expand $(1 + \Delta)^x u_0$ as a rational integral function of x, and also such that the functions of Δ appearing in it shall be capable of interpretation; then to differentiate with regard to x, and equate the result to zero. The appropriate root of the resulting equation thus gives the value of x, and that of u_x is then found by interpolation. As already stated, there is practically an approximate value, obtained at sight, to start the more exact approximation. The most obvious course is to take the ordinary binomial expansion, namely,

$$u = u_0 + \frac{x}{1} \Delta u_0 + \frac{x^2 - x}{2} \Delta^2 u_0 + \frac{x^3 - 3x^2 + 2x}{6} \Delta^3 u_0 + \&c.$$

whence

$$\frac{du}{dx} = 0 = \Delta u_0 + \frac{2x - 1}{2} \Delta^2 u_0 + \frac{3x^2 - 6x + 2}{6} \Delta^3 u_0 + \&c.$$

and this equation has to be solved with respect to x, preferably by successive approximation, after which u is determined. But any other expansion, such as that by symmetrical differences, in which the expansion variable is $\Delta : \sqrt{(1 + \Delta)}$ may also be taken. When the solution is obtained otherwise than by successive approximation, as, for instance, by solving as a quadratic, care must be taken to select the proper root.

Values corresponding to inflexional points in a curve, are, of course, determined by operating in like manner upon $\frac{d^2u}{dx^2}$.

In the use of equidistant ordinates, no difficulty can arise from u and x reaching a maximum together. But when the ordinates are not equidistant, this point requires attention. It presents no other difficulty than is met with in the ordinary theory of implicit maxima.

The case of $\frac{du}{dx} = a$, only differs from that of $\frac{du}{dx} = 0$, as far as work is concerned, by its being less easy to see what the first approximation is to be. Graphical processes, however, or trial and error, soon remove any difficulty.

It must be remembered that the determination of a tangent is of a higher order of precision than the determination of the point of contact. It follows that the determination of the argument corresponding to the maximum or minimum value of a tabulated function is less precise than that of the corresponding value of the function, and also less precise than its determination generally.

Section 7.—Symmetrical Differences.

If the successive values of a function are written down in a column and differenced, the successive differences belonging to a given value run across the scheme in a diagonal line, down or up accordingly as the process is begun from top or bottom. Thus, beginning from the top, the series $u_0 \dots u_n$ gives the following scheme:—

$$\begin{array}{llllll}
u_0 & & & & & \\
 & \Delta u_0 & & & & \\
u_1 \dots & \Delta^2 u_0 & & & & \\
 & \Delta u_1 \dots & \Delta^3 u_0 & & & \\
u_2 \dots & \Delta^2 u_1 \dots & \Delta^4 u_0 & & & \\
 & \Delta u_2 \dots & \Delta_3 u_1 \dots & \Delta^5 u_0 & & \\
u_3 \dots & \Delta^2 u_2 \dots & \Delta^4 u_1 & & & \\
 & \Delta u_3 \dots & \Delta_3 u_2 & & & \\
u_4 \dots & \Delta^2 u_3 & & & & \\
 & \Delta u_4 & & & & \\
u_5 & & & & &
\end{array}$$

This process is essentially unsymmetrical, as is evidenced by its diagonal character. But any horizontal line has symmetry as regards the general scheme, and accordingly the line u_2, $\Delta^2 u_1$, $\Lambda^4 u_0$ is said to be a set of symmetrical differences, that is to say, symmetrical to a value or ordinate. So again the set Δu_2, $\Delta^3 u_1$, $\Delta^5 u_0$ is said to be symmetrical to an interval.

It will be observed that this process is an alternate one—that it is not possible to pass from one column to the next, but always to the next but one. The operative symbol at each actual step, as, for instance, from $\Delta^3 u_1$ to $\Delta^5 u_0$, is always $\Delta^2 : (1 + \Delta)$ and the direct problems of interpolation and quadrature by symmetrical differences are to express $(1 + \Delta)^x$ and $\int u dx$ in a series of ascending powers of $\Delta^2 : 1 + \Delta = Z^2$. It so happens that $(1 + \Delta)^x$ can be expanded by ascending powers of Z_1 but not by powers of Z^2. This introduces terms of the form $\Delta : \sqrt{(1 + \Delta)}$ which cannot be interpreted so long as terms used are confined to one horizontal line, thus implying that the expansion must be a double series. The series itself was given by Newton,* but without proof. The connection between the two parts of the series is a differential one. This is perhaps best shown as follows, using the notation

$$Z = \Delta^2 : (1 + \Delta) = (E - 1)^2 : E = E + E^{-1} - 2,$$

$$M = \frac{1}{2}(E - E^{-1}) = \frac{1}{2}\left(\Delta + \frac{\Delta}{E}\right) = \frac{\Delta(2 + \Delta)}{2(1 + \Delta)}.$$

Solving the first equation with respect to E, gives

$$E = 1 + \Delta = 1 + \frac{1}{2}Z \pm \sqrt{\left(Z + \frac{1}{4}Z^2\right)}$$

$$E^{-1} \qquad = 1 + \frac{1}{2}Z \mp \sqrt{\left(Z + \frac{1}{4}Z^2\right)}$$

The form of these values shows that E and its powers involve, in their

* See his *Methodus Differentialis*, already quoted, Prop. III.; also Stirling, *Methodus Differentialis*, Prop. XX. pp. 104–8; De Morgan, *Calculus*, pp. 544–7, Lacroix, 2nd ed. of his *Calculus*, vol. iii. pp. 26–31 and 327–330.

expansion, both odd and even powers of $\sqrt{Z}$; but that $E^x + E^{-x}$ may be expanded in integral powers of Z, and $E^x - E^{-x}$ in odd powers of $\sqrt{Z}$. Then the differential coefficient of $E^x \pm E^{-x}$ with regard to Z is

$$x\,(E^{x-1} \mp E^{-x-1})\,\frac{dE}{dZ}, \text{ in which } \frac{dZ}{dE} = 1 - E^{-2} = \frac{M}{2E}, \text{ whence}$$

$$\frac{d}{dZ}(E^x \pm E^{-x}) = \frac{x}{2M}(E^x \mp E^{-x})$$

and also

$$E^x = \frac{1}{2}(E^x \pm E^{-x}) + \frac{1}{2}(E^x \mp E^{-x})$$

$$= \left(\frac{1}{2} + \frac{M}{x}\frac{d}{dZ}\right)(E^x \pm E^{-x})$$

If the upper sign be taken, writing

$$\frac{1}{2}(E^x + E^{-x}) = \alpha + \beta Z + \gamma Z^2 + \delta Z^3 + \dots.$$

suitably determining the coefficients $\alpha\,\beta\,\gamma$ ..... and giving the proper interpretation to M, furnishes the formula for interpolation symmetrical to an ordinate; while, if the lower sign be taken, writing

$$\frac{1}{2}(E^x - E^{-x}) = a_1\sqrt{Z} + a_3 Z^{\frac{3}{2}} + a_5 Z^{\frac{5}{2}} + \dots.$$

furnishes the formula for interpolation symmetrical to an interval. The coefficients may be determined either by the ordinary methods of indeterminate coefficients, by the calculus of generating functions, or by writing

$$u_x = c_{-n}u_{-n} + \dots\dots + c_0u_0 + c_1u_1 + \dots\dots c_nu_n$$

and determining the coefficient c in the simplest form, so that $x = rh$ shall make $c_r = 1$ and all the rest vanish.*

The actual formulæ are best expressed in a notation similar to that originally given by Newton and Stirling, namely, for the case symmetrical to an ordinate, in which the differences run,

$$\begin{array}{ccccccc} & \Delta u_{-1} & & \Delta^3 u_{-2} & & \Delta^5 u_{-3} & \\ u_0 & & \Delta^2 u_{-1} & & \Delta^4 u_{-2} & & \Delta^6 u_{-3} \dots\dots \\ & \Delta u_1 & & \Delta^3 u_{-1} & & \Delta^5 u_{-2} & \end{array}$$

$$\text{write } B = \frac{1}{2}(\Delta u_{-1} + \Delta u_1)$$

$$C = \frac{1}{2}(\Delta^3 u_{-2} + \Delta^3 u_{-1})$$

$$D = \frac{1}{2}(\Delta^5 u_{-3} + \Delta^5 u_{-2}) \text{ \&c.}$$

and $a = u_0$, $b = \Delta^2 u_{-1}$, $c = \Delta^4 . u_{-2}$ &c.

so that $C = BZ$, $D = CZ = BZ^2$

and $b = aZ$, $c = bZ = aZ^2$ &c. Then

* See a paper by the author in the *Messenger of Mathematics*, vol. iv. p. 110. Another proof is given by Professor Emory McClintock, of Milwaukee, in the *American Journal of Mathematics, pure and applied*, vol. ii.

$$u_x = a + \left(Bx + \frac{1}{2}bx^2\right)$$
$$+ \left(2Cx + \frac{1}{2}cx^2\right) \times \frac{x^2-1}{3 \,.\, 4}$$
$$+ \left(3Dx + \frac{1}{2}dx^2\right) \times \frac{x^2-1}{3 \,.\, 4} \cdot \frac{x^2-4}{5 \,.\, 6}$$
$$+ \left(5Ex + \frac{1}{2}ex^2\right) \times \frac{x^2-1}{3 \,.\, 4} \cdot \frac{x^2-4}{5 \,.\, 6} \cdot \frac{x^2-9}{7 \,.\, 8} + \&c.$$

the common interval being supposed unity. If the interval is other than unity, say h, the formula must be rendered homogeneous by the substitution of $x : h$ for x.

For the formula symmetrical to an interval, the differences run

$$\begin{array}{ccccccc} u_{-1} & \ldots & \Delta^2 u_{-2} & \ldots & \Delta^4 u_{-3} & \ldots & \\ & \Delta u_{-1} & \ldots & \Delta^3 u_{-2} & \ldots & \Delta^5 u_{-3} & \&c. \\ u_0 & \ldots & \Delta^2 u_{-1} & \ldots & \Delta^4 u_{-2} & \ldots & \end{array}$$

Then writing $A' = \frac{1}{2}(u_{-1} + u_0)$

$$B' = \frac{1}{2}(\Delta^2 u_{-2} + \Delta^2 u_{-1})$$

$$C' = \frac{1}{2}(\Delta^4 u_{-3} + \Delta^4 u_{-2}) \ \&c.$$

and $a' = \Delta u_{-1}$, $b' = \Delta^3 u_{+2}$, $c' = \Delta^5 u_{+3}$ &c.

there is the same relation as before between the successive letters, and the formula is

$$u_x = (A' + a'x)$$
$$+ (3B' + b'x) \quad \frac{4x^2-1}{4 \,.\, 6}$$
$$+ (5C' + c'x) \quad \frac{4x^2-1}{4 \,.\, 6} \quad \frac{4x^2-9}{8 \,.\, 10}$$
$$+ (7D' + d'x) \quad \frac{4x^2-1}{4 \,.\, 6} \quad \frac{4x^2-9}{8 \cdot 10} \quad \frac{4x^2-25}{12 \,.\, 14} + \&c.$$

Making $x = 0$ in this gives the well-known formula of bisection by symmetrical differences, viz.,

$$u_{\frac{1}{2}} = A' - \frac{3B'}{4 \,.\, 6} + \frac{1 \,.\, 9}{4 \,.\, 6 \,.\, 8 \,.\, 10} 5C' - \frac{1 \,.\, 9 \,.\, 25}{4 \,.\, 6 \,.\, 8 \,.\, 10 \,.\, 12 \,.\, 14} 7D' + \&c.$$
$$= A' - \frac{1}{8}B' + \frac{3}{128}C' - \frac{5}{1024}D' + \ldots\ldots$$

Formulæ for quadratures by these symmetrical differences may be at once obtained by integrating Newton's formulæ between $\pm$ limits, in which case the terms involving odd powers of x disappear on integration, leaving only the even differences in the formula symmetrical to an ordinate, and the even mean-differences in the formula symmetrical to an interval. The interval between the ordinates is assumed to be unity. Hence if there are $n + 1$ ordinates the limits will be $\pm \frac{1}{2}(n+1)$, and

not simply 0 to 1 or $\pm\frac{1}{2}$, unless the formula be first duly transformed. Proceeding in this way the following formulæ are obtained.*

Number of Ordinates	Expression for the Area †
1	a
3	$2\left\{a+\frac{1}{6}b\right\}$
5	$4\left\{a+\frac{2}{3}b+\frac{7}{90}c\right\}$
7	$6\left\{a+\frac{3}{2}b+\frac{11}{20}c+\frac{41}{840}d\right\}$
9	$8\left\{a+\frac{8}{3}b+\frac{86}{45}c+\frac{92}{189}d+\frac{989}{28370}e\right\}$
11	$10\left\{a+\frac{25}{6}b+\frac{175}{36}c+\frac{3445}{1512}d+\frac{4045}{9072}e+\frac{16067}{598752}f\right\}$
13	$12\left\{a+6b+\frac{103}{10}c+\frac{158}{7}d+\frac{1833}{700}e+\frac{4813}{11550}f+\frac{1364651}{6306300}g\right\}$

A similar set of formulæ may be obtained, symmetrical to an interval, and in terms of A′, B′ &c.; but the coefficients, as well as the form of the series, are more complicated, and the accuracy somewhat less, on the parabolic hypothesis, than the corresponding rule of the other series. The first rule in this set is the common polygonal rule; the next is got by integrating from $-\frac{3}{2}$ to $+\frac{3}{2}$, and is

$$\text{area} = 3\left(A' + \frac{1}{4}B'\right)$$

which is equivalent to Cotes's rule of four ordinates.

These rules may also be obtained by the direct substitution of symmetrical differences for the ordinates in Cotes's rules, with which they are of course identical, except in form.

The application of symmetrical differences to quadratures may also be made to depend upon the formula

$$\int^n dx^n = \left\{\log\,(1+\Delta)\right\}^{-n}$$

* See Stirling, *Meth. Diff.* p. 148. In the formulæ for 9, 11, and 13 ordinates, Stirling simplifies the numerical coefficient of the final term, just as he has done in the table of corrections for Cotes's rules, apparently for easier use. The practice is not a satisfactory one, as it prevents verification, and saves but little work.

† In the above formulæ the interval between the ordinates is taken as unity. If the whole base is taken as unity, the area is given by omitting the numerical factor outside the $\{\,\}$ The table has been independently computed, and compared with Stirling's table.

It is not, however, commonly used in this form for mere quadrature; but the method is used in the calculation of tables in the form

$$\Delta^m \int^n dx^n = \Delta^m \left\{ \log\ (1 + \Delta) \right\}^{-n}$$

and in most cases in practice, m is taken equal to n. The algebraical process consists in the development of the right-hand side of the last equation in terms of

$$Z = \frac{\Delta^2}{1+\Delta} \text{ or } \Delta = \frac{1}{2} Z + \sqrt{\left(Z + \frac{1}{4} Z^2\right)}$$

$$\log\ (1 + \Delta) = \log \left\{ 1 + \frac{1}{2} Z + \sqrt{Z + \frac{1}{4} Z^2} \right\}$$

$$= \int_0^Z \frac{1}{2\sqrt{Z}} \left(1 + \frac{1}{4} Z\right)^{-\frac{1}{2}} dZ$$

$$= \sqrt{Z} \left\{ 1 - \frac{1}{2} \frac{Z}{3 \cdot 2^2} + \frac{1 \cdot 3}{2 \cdot 4} \frac{Z^2}{5 \cdot 2^4} - \frac{1 \cdot 3 \cdot 5}{2 \cdot 4 \cdot 6} \frac{Z^3}{7 \cdot 2^6} + \ldots\ldots \right\}$$

Representing the mth power of the series in $\{\ \}$ by

$$1 + M_1 Z + M_2 Z^2 + M_3 Z^3 + M_4 Z^4 + \ldots\ldots\ldots,$$

and restoring $\Delta (1 + \Delta)^{-\frac{1}{2}}$ in place of Z

$$\frac{\Delta^m U}{(1+\Delta)^{\frac{m}{2}}} + M_1 \frac{\Delta^{m+2} U}{(1+\Delta)^{\frac{m}{2}+1}} + M_2 \frac{\Delta^{m+4} U}{(1+\Delta)^{\frac{m}{2}+2}} + \ldots\ldots\ldots,$$

which has to be interpreted.

Denote the successive values of u by .... U_n .... U_2, U_1, U or $u, u_1, u_2, u_3, \ldots u_n$, in which $u = \phi\ (x)$, $u_n = \phi\ (x + nh)$, $U_n = \phi\ (x - nh)$. Then the scale of relation is

$U_n = \dfrac{u}{(1 + \Delta)^n}$, $u_n = (1 + \Delta)^n u$. If $u_{\frac{1}{2}}$ or $\phi\left(x + \dfrac{1}{2} u\right)$ be also denoted by V or v, it gives rise to a parallel scale, V_n .... V_1, V or $v, v_1, v_2 \ldots\ldots v_n$, with the same relation between its successive terms, and for its connecting relation with the other scale, $V_r = (1 + \Delta)^{\frac{1}{2}} U_r$.

If m be even $(= 2n)$, direct substitution gives

$$\left\{ \log\ (1 + \Delta) \right\}^{2n} u = \Delta^{2n} U_n + M_1\, \Delta^{2n+2} U_{n+1} + M_2 \Delta^{2n+4} U_{n+2} + \ldots\ldots$$

If m be odd $(= 2n + 1)$,

$$\left\{ \log\ (1 + \Delta) \right\}^{2n+1} U = \Delta^{2n+1} V_{n+1} + M_1 \Delta^{2n+3} V_{n+2} + M_2 \Delta^{2n+5} V_{n+3} + \ldots$$

The values of the coefficients are as follows:—

$$M_1 = -\frac{m}{24}, M_2 = \frac{m}{2^7 \cdot 3^2 \cdot 5}\ (5m + 22),$$

$$M_3 = -\frac{m}{2^{10} \cdot 3^4 \cdot 5^2 \cdot 7}\ (35m^2 + 462m + 1528),$$

$$M_4 = \frac{m}{2^{15} \cdot 3^5 \cdot 5^2 \cdot 7}\ (175m^3 + 4320m^2 + 40724m + 119856);$$

and by giving m any positive or negative value, the series for any differential coefficient or integral may be at once found.

In practice, however, there is frequently a difficulty in using the series, where m is odd, from the values of V, V_1, V_2, &c., not being obtainable without a distinct interpolation, where the values of U, U_1, U_2, U_3, &c., only are given. When m is even, the converse may be the case. This may be obviated by using mean differences, as follows:

Making $Z = \dfrac{\Delta^2}{1+\Delta}$ as before,

$$\frac{2}{2+\Delta} = (1+\Delta)^{-\frac{1}{2}}\left\{1 - \frac{1}{2}\,\frac{Z}{4} + \frac{1\,.\,3}{2\,.\,4}\,\frac{Z^2}{4^2} - \frac{1\,.\,3\,.\,5}{2\,.\,4\,.\,6}\,\frac{Z^3}{4^3} + \ldots\ldots\right\}$$

Combining this with the previous expressions, we get

$$\frac{2}{2+\Delta}\left\{\log(1+\Delta)\right\}^{2n} u = \frac{\Delta^{2n}}{\sqrt{1+\Delta}}\,U_n + N_1\frac{\Delta^{2n+2}}{\sqrt{1+\Delta}}\,U_{n+1} + N_2\,\frac{\Delta^{2n+4}}{\sqrt{1+\Delta}}\,U_{n+2} + \ldots\ldots$$

$$= \Delta^{2n}V_{n+1} + N_1\Delta^{2n+2}V_{n+2} + N_2\Delta^{2n+4}V_{n+3} + \ldots\ldots,$$

N_1, N_2, N_3 being a different set of coefficients.

Now, since $(2+\Delta)V_n = V_n + V_{n-1}$,

$$\left\{\log(1+\Delta)\right\}^{2n} u = \frac{1}{2}\left(\Delta^{2n}V_{n+1} + \Delta^{2n}V_n\right) + \frac{1}{2}N_1\left(\Delta^{2n+2}V_{n+2} + \Delta^2{}_{n+}{}^2V_{n+1}\right) + \frac{1}{2}N_2\left(\Delta^{2n+4}V_{n+3} + \Delta^{2n+4}V_{n+2}\right) + \ldots\ldots;$$

and similarly, when m is odd,

$$\left\{\log(1+\Delta)\right\}^{2n+1} u = \frac{1}{2}\left(\Delta^{2n+1}U_{n+1} + \Delta^{2n+1}U_n\right) + \frac{1}{2}N_1\left(\Delta^{2n+3}U_{n+2} + \Delta^{2n+3}U_{n+1}\right) + \frac{1}{2}N_2\left(\Delta^{2n+5}U_{n+3} + \Delta^{2n+5}U_{n+2}\right) + \ldots\ldots$$

The values of the coefficients N are as follows:—

$$N_1 = -\frac{1}{24}(m+3),\ N_2 = \frac{1}{2^7\,.\,3^2\,.\,5}(5m^2 + 52m + 135),$$

$$N_3 = -\frac{1}{2^{10}\,.\,3^4\,.\,5\,.\,7}(35m^3 + 777m^2 + 5749m + 14175),$$

$$N_4 = \frac{1}{2^{15}\,.\,3^5\,.\,5^2\,.\,7}(175m^4 + 5720m^3 + 96794m^2 + 619776m + 1488375).$$

Remember that the sum of two successive differences is the difference of alternate numbers in the preceding column.

The formulæ most frequently occurring in practice are, for integrals,*

$$\frac{1}{h}\Delta\int u\,dx = \frac{1}{2}(u + u_1) - \frac{1}{24}(\Delta^2U_1 + \Delta^2u) + \frac{11}{720}(\Delta^4U_2 + \Delta^4U_1)$$

* The higher coefficients cannot be relied upon for accuracy. They were calculated, with some care, many years ago; but they are not of much practical use, and have not been satisfactorily verified.

$$-\frac{191}{210\,.\,2^6}(\Delta^6U_3+\Delta^6U_2)+\frac{119981}{170100\,.\,2^{11}}(\Delta^8U_4+\Delta^8U_3)-\ldots.$$

$$\frac{1}{h}\Delta\int udx=V+\frac{1}{24}\Delta^2V_1-\frac{17}{5760}\Delta^4V_5+\frac{367}{1890\,.\,2^9}\Delta^6V_6-\frac{27859}{56700\,.\,2^{14}}$$
$$\Delta^8V_4+\frac{1295803}{1871100\,.\,2^{16}}\Delta^{10}V_5-\frac{15183675231}{7662154500\,.\,2^{20}}\Delta^{12}V_6+\ldots\ldots..$$

$$\frac{1}{h^2}\Delta^2\int udx^2=u_1+\frac{1}{12}\Delta^2u-\frac{1}{240}\Delta^4U_1+\frac{31}{1890\,.\,2^5}\Delta^6U_2-$$
$$\frac{289}{56700\,.\,2^6}\Delta^8U_3+\ldots.$$

Most of Legendre's tables of definite integrals were computed by the second or third of these formulæ. His great table of elliptic functions was calculated by the second.

For differential coefficients

$$h\frac{du}{dx}=\frac{1}{2}(\Delta U_1+\Delta u)-\frac{1}{12}(\Delta^3U_2+\Delta^3U_1)+\frac{1}{60}(\Delta^5U_3+\Delta^5U_1)$$
$$-\frac{1}{280}(\Delta^7U_4+\Delta^7U_3)+\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$=\Delta V_1+\frac{1}{3\,.\,2^3}\Delta^3V_2+\frac{3}{5\,.\,2^7}\Delta^5V_3-\frac{4}{7\,.\,2^{10}}\Delta^7V_4$$
$$+\frac{35}{9\,.\,2^{15}}\Delta^9V_5-\ldots\ldots$$

If $m=0$ in the N formula, it becomes

$$u=\frac{1}{2}(V_1+V)-\frac{1}{2^4}(\Delta^2V_2+\Delta^2V_1)+\frac{3}{2^8}(\Delta^4V_3+\Delta^4V_2)$$
$$-\frac{5}{2^{11}}(\Delta^6V_4+\Delta^6V_3)+\frac{35}{2^{16}}(\Delta^8V_5+\Delta^8V_4)-\ldots\ldots,$$

a well-known formula of bisection.

Some obvious transformations will enable corresponding formulæ to be obtained for $\Delta^m\int^n dx^n$ where m and n are different.*

It is to be observed that the formula for integration above given is not $\int udx$, but $\frac{1}{n}\Delta\int udx$, which is a different thing. If $\int udx$ itself be required, it must be obtained by summation.

A very compendious method of interpolating tables by means of bisection is derivable from the ordinary formula of bisection, by affecting it with Δ. Thus, stopping at the first term, namely, $u=\frac{1}{2}(V_1+V)$

$$\Delta u=\frac{1}{2}(\Delta V_1+\Delta V)$$
$$=\Delta V_1+\frac{1}{2}\Delta^2V_1$$
$$=\Delta V-\frac{1}{2}\Delta^2V.$$

* See Woolhouse on 'Interpolation, Summation, &c.' in the *Assurance Magazine*, vol. xi. p. 301 *et seq.* for some interesting transformations of these theorems.

If the second difference is small, the correction for the alternate difference is very easy. A particular case of this formula was suggested by Sir John Leslie * for continuing either Briggs' or Vlacq's logarithm tables. For the difference between the logarithms of (say 11000 and 11002 is the same as between those of 5500 and 5501, and the formula given above enables us to find from it the difference between the logarithms of 10099 and 11001, and so on, so that the odd series can thus be quickly calculated, and the extension of the table to double its former range effected with very little more than mere copying. 'Mere copying,' however, when applied to an extensive table of logarithms, is so laborious, and such a fruitful source of error, that this application of the method has never been made. Nevertheless, it is a very convenient process for interpolating tables of physical or other observations, where the second difference is not very considerable.

Section 8.—*Definite or Tabular Interpolation.*

The problem of definite or tabular interpolation is this: given a table, or a set of differences, corresponding to a given equal interval; to construct from it a table corresponding to some other equal interval, usually a sub-multiple of the former. For example, suppose a function to be tabulated (or given by differences) for every ten minutes, and that it is required to find the means of tabulating it to every minute; it would be possible to interpolate separately to every intermediate value; but this would be unreasonably laborious, and what is usually needed is to find a set of differences corresponding to the reduced interval, from which the table may be set up, either by arithmetical summation, or by a difference engine.

Let Δ be the symbol of differencing for the wider interval, and δ for the smaller interval, and let

$$E = 1 + \Delta, e = 1 + d$$

then the fundamental relation between the two scales is $E = e^m$, and the analytical problem is simply to express a selected function of e in terms either of E, or of a selected system of functions of it. The equation $E = e^m$ arises simply from a comparison of the original and interpolated series, namely,

original series $U_0 \ldots\ldots U_1 \ldots\ldots\ldots\ldots U_2 \ldots\ldots$

interpolated series, $u_0 \, u_1 \, u_2 \ldots u_{m-1} \, u_m \, u_{m+1} \, u_{m+2} \ldots u_{2m-1} \, u_{2m} \ldots$

$$\text{Where } U_0 = u_0, E\,U_0 = U_1 = U_m = e^m u_0,$$
$$E^2 U_0 = E\,U_1 = U_2 = U_{2m} = e^m u_m = e^{2m} u_0, \text{ \&c.}$$

All the remainder of the work consists, firstly, of algebraical transformation; and, secondly, of the actual arithmetic. The kind of transformation needed turns, firstly, upon how the E's are expressed; secondly, upon how it is desired to express the e's. Thus the E's may be expressed either by a mere tabulated series $U_0, U_1, U_2, U_3 \ldots\ldots$, that is, by powers of E; or by U_0 and its ordinary differences, that is, by ascending powers of Δ or $E - 1$; or again by symmetrical differences, that is, by powers of $Z = \Delta^2 : (1 + \Delta)$; or even by ascending differences, that is to say, by powers of $\Delta : (1 + \Delta)$. So it may be desired to express the interpolation by powers of e, of d or $e - 1$, of $z = d^2 : (1 + d)$ or of

* See the article 'Logarithms,' in the recent editions of the *Encycl. Britannica*. The article originally appeared in the supplement to the fourth edition.

$d : (1 + d)$, and in any case the problem is simply the analytical expression of any such function of e in terms of the selected function of E. The assumption, that U_0 and u_0 should coincide, is not a necessary one. The only effect of their not coinciding is to substitute the equation $E^n = e^{mn+r}$ for the simpler form $E^n = e^{mn}$.

An exposition of the application of this method to symmetrical differences appears to have been first given by Henry Briggs in his *Arithmetica Logarithmica*, published in 1824. But it appears from his preface that the tables of sines, afterwards published by Gellibrand in the *Trigonometria Britannica*, had been calculated by Briggs, by a more or less complete application of these rules, twenty years earlier.* His exposition is, however, not very well suited to modern use, being rather too much specialised, with a view of suiting his own work. A more general exposition of the method is given by Roger Cotes in his *Canonotechnia, sive constructio tabularum per differentias.*† This, besides general rules, contains the tabulated coefficients for the bisection, trisection, and quinquisection of the interval. It does not appear that the subject was resumed until recently, when Mr. Woolhouse gave both tables and formulæ for the division of the interval by 5 and by 10.‡

According to Lacroix, the method of tabular interpolation for ordinary differences was first published by Mouton, to whom it was given by his friend Regnaud, in 1670, and afterwards reduced to a general formula by Lagrange and Prony. The method is as follows. Let $u_0\, u_1\, u_2 \ldots\ldots$ be a series of numbers, of which the fourth difference may be neglected, and suppose that it is desired to obtain the differences for interpolating two numbers between each. Let the required differences be b, c, d, the original differences being represented in the usual way by Δu_0, $\Delta_2 u_0$, &c. Then, if the interpolated series u_0, $u_0 + b$, $u_0 + 2\,b + c$, &c. be formed, and the terms representing $u_0\, u_1$ &c. be picked out, they give

$$\begin{aligned} u_0 &= u_0 \\ u_1 &= u_0 + 3b + 3c + d \\ u_2 &= u_0 + 6b + 15c + 20d \\ u_3 &= u_0 + 9b + 36c + 84d \end{aligned}$$

and differencing these,

$$\begin{aligned} \Delta u_0 &= 3b + 3c + d \\ \Delta^2 u_0 &= 9c + 18d \\ \Delta^3 u_0 &= 27d \end{aligned}$$

solving these as a set of simultaneous equations,

$$b = \frac{1}{3}\Delta u_0 - \frac{1}{9}\Delta^2 u_0 + \frac{5}{81}\Delta^3 u_0$$

$$c = \frac{1}{9}\Delta^2 u_0 - \frac{2}{27}\Delta^3 u_0$$

$$d = \frac{1}{27}\Delta^3 u_0 \ \S$$

* Briggs's words are 'Nam Differentiæ, quæ ante annos viginti mihi maximo usui fuerunt in novo canone sinuum condendo, in horum Logarithmorum calculo sunt mihi multo melius perspectæ et cognitæ.' An explanation and proof of Briggs's method of quinquisection are given by Legendre in the *Connaissance des Temps* for 1817, p. 219.

† Published in the same volume with the *Harmonia Mensurarum*, by R. Smith, Cambridge, 1722.

‡ Vide *op. cit.* part ii. Also *Assurance Magazine*, vol. xi. p. 61 *et seq.*

§ For the general formula see Lacroix, *Traité de Calcul.* vol. iii. p. 43.

The tables given by Cotes and Woolhouse for symmetrical differences appear to have been formed upon the same principle.

A question of some interest in the interpolation of tables, in which the number tabulated is only approximately correct, is whether it is preferable to apply proportional parts to the true calculated difference of the function, or to the actual tabular difference. Thus in the seven-figure logarithms

$$\log 66310 = 4{\cdot}8215790$$
$$\log 66311 = 4{\cdot}8215856$$

the tabular difference is 66, while the correct difference as obtained from Vega's ten-figure table is 65494, which, to seven figures, is only 65. The question is, whether it is better to use 65 or 66 for finding the proportional parts. By a comparison of the extreme cases, M. Lefort* has shown that so long as the tabular difference (that is to say, the difference actually found between the numbers as given in the table) is used, the last figure in the interpolated result cannot be in error by more than unity; while if the true calculated difference, cut down to the nearest figure, be used, the last figure may be in error by more than unity. It follows that the actual difference of the table, and not the mean difference given in some tables (such as Hutton and Callet), should be used for the interpolation.

Section 9.—Interpolation of Double Entry Tables, or Functions of two or more Variables.

The problem of the interpolation of functions of two variables presents but few difficulties beyond those of interpolation of functions of a single variable, excepting what is due to the increased complexity of the process. This renders many of the special artifices practically unmanageable, although the very fact of the complexity increases the importance of simplifying the actual work. Nevertheless, it is better on the whole, in processes which are not of frequent use, to encounter deliberately a little excess of arithmetical labour, rather than to risk the chances of error from want of analytical simplicity and perspicuity. If any one process should be often wanted, those who need it may be left to invent the special machinery.

The general theorem of interpolation for double entry is expressed in the two formal identities.

$$u_{xy} = f(x,y)$$
$$u_{xy} = (1+\Delta)^x (1+\delta)^y u_{0\,0}$$

in which Δ refers to variation with regard to x, on the supposition that y is constant, and δ refers to variation with regard to y, on the supposition that x is constant.

In general it is usual to give equal weight to the two variations, that is to say, that if it is proposed to neglect terms of the order p, then all terms of the form $\Delta^m \delta^n$, where $m+n=p$, are to be discarded, whatever may be the separate values (always supposed positive) of m and n. The terms of the expansion would thus be grouped as

$$\begin{aligned} u_{xy} = {} & u_{0\,0} \\ & + (x\Delta + y\delta)\, u_{0\,0} \end{aligned}$$

* See the *Proceedings of the Royal Soc. of Edinburgh*, vol. viii. (1875), p. 610.

$$+\frac{1}{2}(x^2\Delta^2 + 2xy\,\Delta\delta + y^2\,\delta^2)\,u_{0\,0}$$

$$+ \ldots\ldots\ldots$$

But this supposition is entirely arbitrary, and not even justifiable if it happens to be known that the second and higher differences are considerably greater in one direction than in the other. This, and the remedy for it, are only to be ascertained by a special study of the function.

In accordance with common practice, the direct expansion by ordinary differences has been used; but there is no motive for this except convenience and simplicity. Subject to the difficulties of interpretation and handling which they introduce, any form of the expansion

$$u_{xy} = (1+\Delta)^x\,(1+\Delta)^y\,u_{0\,0} = \mathrm{E}^x\,\mathrm{E}^y\,u_{0\,0}$$

will answer the purpose. There are even cases in which it would be desirable to form an interpolated table for the given value of one variable on the supposition that the other is constant, and then to interpolate that as a single entry table.

Thus, supposing that going along a line in the table represents the variation of y, and going down a column represents the variation of x, then the whole column corresponding to a particular value of y might be interpolated, value by value, so as to give the series arranged in *column*

$$u_{0y}\,u_{1y}\,u_{2y}\,u_{3y}\,\ldots\ldots$$

and then interpolation to u_{xy} might be effected by single entry; or the process might be reversed, and the *line*

$$u_{x0}\,u_{x1}\,u_{x2}\,u_{x3}\,\ldots\ldots$$

formed first, and then u_{xy} by single entry interpolation.

It is worth while to remark that the interpolation may occasionally be reduced to single entry interpolation along a diagonal line. This is always the case in *bisection*; but it is by no means confined to that case.

The inverse problem of interpolation is in general of a higher order of indeterminateness, unless some other data are given than the mere value of the ordinate. For if the two variables be regarded as horizontal, and the function as representing a vertical ordinate, then the ordinate being given in value, merely furnishes a *locus*, namely, a level line. So if one of the variables be given, a special table may be formed for that value of the variable, and then the inverse interpolation is an operation of single entry. But if, instead of this, some equation be given between x and y, the problem falls out of the province of direct synthesis, unless the relation between x and y be that they are in a constant ratio. The analogy is of course that of the representation of a surface in geometry of three dimensions, and that analogy is really the key to the question.

An example of the interpolation of a double entry table as far as third differences is given by Legendre.*

Quadrature in two dimensions is really equivalent to the evaluation of solid volume. The two quadratures may be effected either separately, or by the methods indicated in Section IV, 4, of this report.

Another problem arising out of a double entry table is that of inter-

* *Traité des Fonctions Elliptiques*, vol. ii. p. 201 (cap. xv.)

polation to the direction of a normal line or tangent plane. This, in the ordinary language of partial differential coefficients, is the evaluation of

$$\sqrt{\left\{1 + p^2 + q^2\right\}}.$$

The first thing is to find p and q by the methods for interpolation of ordinates (IV, 6) and then to form the radical. Graphical methods are, however, generally the most convenient for this. The integration of this radical in two dimensions gives the surface. For an example of this particular form of interpolation combined with quadrature, see Scott Russell's 'Modern Naval Architecture,' and the 'Transactions of the Institution of Naval Architects,' vol. vi. for 1865, p. 64.

Tables of treble (or higher multiples) entry are of course confined within very narrow limits. Their interpolation calls for no special remark, unless it be that the indeterminateness, as well as the complexity, increases with every additional dimension. This remark is true, as a separate consideration, firstly with regard to the general indeterminateness of all interpolation, and secondly with regard to the indeterminateness of the inverse processes, with reference to the possibility of more roots than one, and to the requirement of more data than the ordinate.*

V.—Interpolation and Quadrature with Ordinates not equidistant.

Section 1.—*Newton's method.*

The principal theorem of interpolation when the distances between the ordinates are arbitrary instead of equidistant, is given by Newton, in his 'Principia,'† under this title, 'Invenire lineam curvam generis parabolici quæ per data quotcumque puncta transibit.' It consists of a method of divided differences, and Newton uses it in a form which is, as exactly as may be, the counterpart of that which he uses when the ordinates are equidistant. It is not thought necessary to reproduce it here, as the reference to it is very easy.‡

Professor Emory McClintock, of Milwaukee, has given § a modification of Newton's formula, which lends itself better to logarithmic computation. The terms being ϕx_1 or $\phi_0 x_1$, ϕx_2 or $\phi_0 x_2$, and so forth, the general term of his divided differences is

$$\phi_{m+1}\, x_n = \frac{\phi_m\, x_n - \phi_m\, x_{m+1}}{x_n - x_{m+1}}$$

which gives, on multiplying up,

$$\phi_m\, x_n = \phi_m\, x_{m+1} + (x_n - x_{m+1})\, \phi_{m+1}\, x_n.$$

Giving m the values 0, 1, 2, &c. in succession, and substituting successively, we get

$$\phi_0\, x_n = \phi_0\, x_1 + (x_n - x_1)\, \phi_1\, x_2 + (x_n - x_1)\,(x_n - x_2)\, \phi_2\, x_3$$
$$+ (x_n - x_1)\,(x_n - x_2)\,(x_n - x_3)\, \phi_3\, x_4 + \ldots\ldots$$

* See on this G. Darwin, on 'Fallible measures of variable quantities,' *London, Edin. and Dublin Philos. Mag.* for July, 1877. See also Lacroix, *Traité de Calcul*, vol. iii. p. 44 *et seq.* (arts. 913 *et seq*).

† Book iii. Prop. xl. Lemma V. case 2; see also his *Methodus Differentialis*, Prop. iv.

‡ See also De Morgan, *Calculus*, p. 550; Lacroix, *Traité de Calcul*, vol. iii. p. 31, *et seq.*—or page 552 of the Cambridge translation. See also Stirling, *Interpolatio Serierum*, Prop. xxix., and Hall, 'Finite Differences,' *Encycl. Metrop.* p. 249.

§ See the *American Journal of Mathematics, pure and applied*, vol. ii. pp. 307-314.

which, if a fractional value be given to n, becomes a formula of interpolation.

Section 2.—Lagrange's method.

Lagrange's theorem of interpolation, although identical in its results with Newton's, is in a form analogous rather to the case of ordinates not differenced, than to the use of differences, which is the analogy followed by Newton. As is well known, it depends upon

$$X_0 = \frac{(x - a_1)\,(x - a_2)\,\ldots\ldots\,(x - a)}{(a_0 - a_1)\,(a_0 - a_2)\,\ldots\ldots\,(a_0 - a_u)}$$

becoming unity for $x = a_0$, and vanishing when x is equated to any other of the quantities $a_1\,a_2\,a_3\,\ldots\,a_n$. Then interchanging a_0 with $a_1\,a_2$ &c. in succession, so as to obtain a series of quantities $X_0\,X_1\,X_2\,\ldots\,X_n$, the formula of interpolation is

$$u_x = X_0\,u_0 + X_1\,u_1 + X_2\,u_2\,\ldots\ldots + X_n\,u_n$$

The proof consists in the observation that since $X_r = 1$, and all the other X*s* vanish when $x = a_r$ it leaves $u_x = u_r$ as it ought to do. Although this formula usually bears Lagrange's name, it is said to be really due to Euler. The chief advantage of it over Newton's method is, that the coefficients are in a form adapted to logarithmic computation.

The differential coefficients of u_x with regard to x may be obtained by actually differentiating the resulting formula, either in Newton's or in Lagrange's method. But they may also be obtained, as in the common theory of equations, by an obvious application of Maclaurin's theorem.*

The quadrature can also be effected, as was pointed out by Newton, by the application of the ordinary methods for the measurement of an area of parabolic form. It does not appear that the details have as yet received much attention, but it is evident that the final formula of either Newton or Lagrange may be integrated between limits, by direct integration, and that the result of the integration may be expressed in terms of the intervals and ordinates, either by direct substitution, or by the help of indeterminate coefficients. Judging from the form in which Laplace has placed the differential coefficients, it is probable that some interesting results would be obtained by such an investigation; but these results would be likely to be more interesting as a matter of form, than useful as a matter of arithmetic.

Section 3.—Gauss's Method of Quadrature.

This method is of high analytical interest, as connecting the theory of interpolation with what are known indifferently as Spherical Harmonics, or as Lagrange's or Laplace's functions. It is also useful and interesting from the point of view of their inventor, in making the best possible use of a small number of ordinates, when the function subjected to this mode of quadrature is capable of exact expression in a parabolic form. If this last condition be not assured, its arithmetical value also becomes in a like degree uncertain. It has assuredly never been proved that there is any general advantage in adapting the rules, indicated by the parabolic theory as the most exact, to cases which are not known to fall strictly within that theory.

* See Boole's *Finite Differences*, 2nd edit. p. 41.

Gauss's proposal is to select the abscissæ in such a manner that the error of a quadrature, obtained by means of n selected ordinates, shall disappear in the application of this quadrature to any rational function not exceeding the degree of $2n-1$. For this purpose, supposing the limits of integration to be $\pm\frac{1}{2}$ the abscissæ are the n roots of the equation

$$\frac{d^n}{dx^n}\left(x^2-\frac{1}{4}\right)^n=0$$

which are the halves of the roots obtained by equating to zero the coefficients of Legendre.* Thus the multipliers for quadrature are easily obtained by substitution or by indeterminate coefficients. The roots of the sets up to $n=5$ can be obtained as quadratic surds, and, with the coefficients, are as follows:

$$n=1,\ x=0,\ c_1=1$$

$$n=2,\ x^2=\frac{1}{12},\ c_1=c_2=\frac{1}{2}$$

$$n=3,\ x^2=\frac{3}{20}\text{ or }x=0$$

$$c_1=c_3=\frac{5}{18},\ c_2=\frac{4}{9}$$

$$n=4,\ x^2=\frac{1}{140}(15\pm 2\sqrt{30})$$

$$c_1=c_4=\frac{1}{4}-\frac{1}{72}\sqrt{30}$$

$$c_2=c_3=\frac{1}{4}+\frac{1}{72}\sqrt{30}$$

$$n=5,\ x^2=\frac{1}{252}(35\pm 2\sqrt{70})\text{ or }x=0$$

$$c_1=c_5=\frac{322-13\sqrt{70}}{1800}$$

$$c_2=c_4=\frac{322+13\sqrt{70}}{1800}$$

$$c_3=\frac{519}{1800}\pm\frac{64}{225}\dagger$$

Section 4.—*Other Methods and Suppositions.*

For some extensions of Gauss's method, and for some particular forms

* See Legendre, *Fonctions Elliptiques*, vol. ii. p. 531; Todhunter on the *Functions of Laplace, &c.*, chapter x.; Boole, *Finite Differences*, 2nd edit. p. 51, (ch. iii. art 12); Bertrand, *Calcul Intégral*, p. 339. Gauss's own memoir is *Methodus nova integralium valores per approximationem inveniendi.* Göttingen—Comm. III. [1814] *Nouv. Ann. Math.* xv. (1856).

† The numerical values of these and of some of their logarithms are given by Gauss, Bertrand, and Todhunter in the works already quoted. The limits of error are also fully discussed by the two latter. But an attentive perusal of Bertrand's reasoning will show that the limit of error depends upon the convergency of the parabolic expression of the function, and cannot be relied upon where this is not secured.

of the other theorems of interpolation, the reader is referred to Mr. Moulton's notes to ch. iii. of Boole's 'Finite Differences,' second edition, and to the examples of the same chapter. The extensions of Gauss's method are of too special application to need exposition here, especially considering their very doubtful utility in dealing with actual, as distinguished from analytical, data.

It is important to observe that both Newton's and Cotes's methods admit of a far wider generalisation of form. The parabolic character of the assumption usually made, that the function subjected to interpolation or quadrature is either a rational integral function of the variable, or a convergent series, is not by any means necessary. On the contrary, the very form of Lagrange's expression shows that it is permissible to substitute for the simple factors, functions of those factors arbitrarily chosen, with only such restriction as to form as is needed to prevent the formula becoming confused or nugatory.* This is merely another way of stating the essentially indeterminate character of interpolation. It has to be shown, as a prior condition of the use of any such specialised formula, that there is good reason for applying it, and that its results are reliable. The reason for *generally* selecting the ordinary methods turns upon the two principles, that a function can be approximately represented by a convergent rational series, and that the approximation can be made as great as we please by taking the intervals sufficiently small. It has already been pointed out that these principles are not universally true, and, as particular cases, that they are not so when there is either physical discontinuity, or discontinuity within the meaning given to it in the proofs of Taylor's theorem. An examination into the questions corresponding to these is needed in using any such functional substitute for the simple factors of the parabolic assumption, in order to render the method safe and complete. There are doubtless many cases in which this may be practically neglected. In those cases there may be a doubt as to the necessity for any such refinement at all, except as a mere matter of selecting the proper function for interpolation,† and indeed the complete investigation frequently amounts, in the end, to nothing more than doing this. It even sometimes brings back the question to the determination of an analytical expression which shall adequately represent the table or series of observations. A very remarkable instance of this is the representation, due to the late Benjamin Gompertz,‡ of the decrements of life by means of a double exponential function. The equivalent physical assumption is that the stock of vital force undergoes a weakening proportional to the time, and this assumption, not improbable in itself, is found, with a suitable determination of the parameters in each case, to represent, with a high degree of accuracy, all the best life-tables, through

* This may very well happen if very general forms are incautiously subjected to special interpretation, or if special forms are incautiously generalised. $\phi^{-1}\,\phi x$ is a well-known example of this trap for the unwary.

† Cf. Stirling, *Methodus Diff.* p. 88, 'Nam interpolatio non est temere suscipienda, sed ante exordium operis inquirendum est quænam sit Series simplicissima, ex cujus intercalatione pendet ea seriei propositæ. Atque hæc præparatio est magna ex parte omnino necessaria, ut deveniamus ad conclusiones concinnas et elegantes.'

‡ The formula is $dy = -ab^x y\,dx$, where y is the number living at the end of x years. See Gompertz 'On the nature of the Function expressive of the law of Human Mortality,' *Philos. Trans.* 1825, p. 513. See also another paper by the same author, *Phil. Trans.* 1862, p. 571. See also the article 'Mortality' in the *Penny Cyclopædia* and in the *English Cyclopædia* (Arts and Sciences).

a very considerable portion of their range. Nevertheless its insufficiency is shown by its being impossible to apply the rule to the whole range of the observed life-table (including infant and senile life), without either losing accuracy, or introducing a discontinuous change into the parameters. Investigations of this description, however, belong rather to analysis than to mere interpolation. Their importance can hardly be overrated, especially when functions involving more than one parameter have to be considered; for tables of double entry are very cumbrous, and to go beyond that is practically impossible. Hence the importance of Gompertz's formula, and the corresponding importance of those of Jacobi's investigations* which have rendered it possible to reduce the evaluation of elliptic functions, primarily depending upon three variable quantities, to a combination of results obtained from interpolating double-entry tables. It seemed advisable to point out the bearing of these considerations upon the subject of interpolation, although their detailed exposition lies outside the scope of this report.

VI.—Interpolation and Quadrature for Uncertain Values.

When a number of observations of a phenomenon, which can yield but a single numerical value, have to be compared, the ordinary theory of the errors of observation furnishes the most probable numerical amount of that value, or of any given function of that value; and this whether the observations be all equally good, or have definite numerical weights attached to each. A further refinement has been introduced by attaching weights themselves derived from the departure of the individual observations from the first mean. This is a perfectly definite process, and the only remark which needs to be made upon it here is, that the most probable value of a given function of the result is not the same thing as the given function of the most probable value of the result.

When an unknown curve is only known by a number of points, each determined subject to some unknown but appreciable error, the problem of finding the curve is absolutely indeterminate, unless some assumption be made as to the nature of the curve. This will be best seen by taking an easy problem, in which the indeterminateness is removed by a simple supposition. Let us assume that a right line has been observed, and is to be plotted by means of a set of equidistant ordinates, but that upon setting them off, the heads are not in a right line. It is then a perfectly definite problem to find a right line such that the squares of the distances of the points from it shall be a minimum, and in accordance with the fundamental principle of the ordinary theory, we shall find the same right line in whatever uniform direction we measure the distances. But the assumption that the line through the observed points is a right line, is exactly what we want to avoid in the general problem. On the other hand, when points of a curve are definitely given, we may make the curve determinate by assuming that its continuity is of the highest order possible. In its simplest form this is effected by assuming the curve to have a parabolic equation; but this is not essential, and we may settle it by circular curvature instead of by parabolic order. But whatever law

* See Legendre, *Traité des Fonctions Elliptiques*, vol. iii. pp. 141-2 (2nd supp. art 171); also Jacobi, *Fundamenta nova Theoriæ Functionum Ellipticarum*, pp. 139, 140.

of facility we take for the nature of the curve connecting the points, that is evidently independent of the law by which the points are assumed, and there is no law connecting the two systems of probability. Any attempt to attain determinateness is therefore of necessity futile.

This indeterminateness is experienced in practice as well as indicated by theory. One of the commonest modes of 'fairing' a curve through given points is by using a flexible batten, or spline, which is pinned down by lead weights to the points through which the curve is to be drawn, and the pen is then drawn along the batten. Now, in practice, it is found impossible to use similar battens for all curves. The batten has to be weakest where the curvature is the greatest, and it is a matter of taste and discrimination to select a batten with the proper taper, and to use it discreetly, so as to get a reasonable and presentable result. The use of moulds or curved patterns is still more a matter of eye.

In the case of a curved surface such as that of a ship, the problem is rendered somewhat more determinate by the consideration that all the sections, and all their projections, must be fair curves. The two sets of vertical sections, and the water sections, thus correct one another, and it is not an uncommon thing to complete the 'fairing' by means of diagonal lines. Another mode, nearly equivalent, is to make a model, and to work it until it is not only quite smooth, but until, when it is held up in every possible light, the shadows fall evenly and fairly upon it. This is quite as severe a test as the drawing. Nevertheless, in either case the adjustment is not a matter of rule, but of taste and judgment. Apart from the mechanical skill necessary to produce such work, there are many people whose perceptions are not sufficiently delicate to appreciate or test it.

While the problem is thus really and intrinsically indeterminate, all the solutions being strictly *secundum quid*, instead of being general, the difficulty is by no means beyond the reach of practical skill in the most useful cases. A comparatively small number of sections in two dimensions will enable two experienced draughtsmen to produce a couple of ships which shall differ very little in size or shape when they come to be built.

It may be worth while to repeat that the indeterminateness really turns upon the want of any arithmetical comparison between two independent systems of variation of error, or of any analytical means of combining them so as to give a single determinate result.*

* On this subject see Mr. G. H. Darwin on 'Graphical Interpolation and Integration,' *Messenger of Mathematics*, January 1877, p. 134, and the same author on 'Fallible Measures of Variable Quantities,' *Philos. Mag.* for July 1877. In the former paper Mr. Darwin gives a simple proof that the use of the trapezoidal rule gives a less probable error for the area of a curve, when the ordinates are taken as having each the same possible numerical error, than is given by the higher parabolic rules. The arbitrariness of this assumption as to the law of error should not pass unnoticed.

See also a paper by Mr. Eckart in the *Transactions of the Institution of Naval Architects*, vol. xiii. (1872) p. 318 and plate xv., for an example of a fair curve drawn through a series of points whose positions require correction. See, further, a paper by Dr. McAlister in the *Quarterly Journal of Mathematics* for this year (1880), on the use of the Geometrical Mean for giving the most probable result. This is equivalent to using the logarithms of the terms, instead of the actual terms, in the equation of probability.

VII.—Periodicity.

The ordinary assumption of interpolation is that there shall be no periodicity in the function, and this assumption is involved in the approximate equation virtually assigned to the curve being of parabolic form. Any periodicity vitiates the accuracy of the result, and the detection of this periodicity is necessary before any correction can be applied, or any special methods adapted to the periodic character.

In observed results, rather long series are required before periodicity can be detected, unless it can be independently inferred from analytical or physical considerations. It is best detected by plotting a curve of the function, and the process may be facilitated by first transforming the function so as to deprive it of any very abrupt curvature. The oscillation will then generally become visible, or may be made so by an elliptic exaggeration of ordinates, taken nearly normal to the general direction of the curve.

The arithmetical methods of detecting periodicity are mere transformations of this geometrical principle. They are very difficult and intricate pieces of work, especially when the periodicity is of high order and small amplitude. Examples may be seen in the discussions of the inequalities of the planetary systems in astronomical works, and, in a less elaborate way, in the discussion of the various periodicities which have been associated with the sun-spot period.* They also present themselves in the discussion of tides; but in these cases the probability of a period is sufficiently evident to cause it to be looked for in the proper way.

When the period is once found, there is seldom much difficulty in dealing with it, either for interpolation or for quadrature.

VIII.—Systematic Computation of Quadratures and Interpolations.

In all work connected with either interpolation or quadrature it is necessary, both for convenience and correctness, to do the work in a neat and well-arranged tabular form. The expression given in many books for the parabolic quadrature, namely, 'to the sum of the first and last ordinates add four times the sum of all the even ordinates, and twice the sum of all the other ordinates, and multiply the total by one-third of the interval' is not the form in which any practised computer would think of working. The slight repetition of labour involved in the tabular form is as nothing compared with the trouble and chance of error involved in disturbing the regular order of the ordinates. Moreover, when moments are required, as well as mere area, the tabular arrangement is a clear gain of work. An example of the arrangement for obtaining the centre of gravity of a curvilinear area is given below. The curve selected for integration is $y = 2\sqrt{(x+1)} - 2$, for the values 0, 1, 2, 3, 4, 5, 6 of x.

The result is that the area is 11·3568, and that the coördinates of the centre of gravity are

$$\frac{43 \cdot 5586}{11 \cdot 3578} = 3 \cdot 8377, \text{ and } \frac{13 \cdot 2840}{11 \cdot 3578} = 1 \cdot 1696.$$

* See also Messrs. C. & F. Chambers 'On the Mathematical Expression of Observations of Complex Periodical Phenomena,' *Phil. Trans.* vol. 165 (for 1875) p. 361.

	y		$\int y\,dx$	x	$\int xy\,dx$	y^2		$\int y^2dx$	
Number of ordinate	Ordinate	Multiplier for integration	Product for area	Multiplier for moment	Product for moment	Square of ordinate	Multiplier for integration	Product for moment	Number of ordinate
1	0·	1	0·	0	0·	0·	1	0·	1
2	0·8284	4	3·3136	1	3·3136	0·6862	4	2·7448	2
3	1·4641	2	2·9282	2	5·8564	2·1433	2	4·2866	3
4	2·	4	8·	3	24·	4·	4	16·	4
5	2·4721	2	4·9442	4	19·7768	6·1110	2	12·2220	5
6	2·8990	4	11·5960	5	57·9800	8·4042	4	33·6168	6
7	3·2915	1	3·2915	6	19·7490	10·8338	1	10·8338	7
—	—	—	34·0735	—	130·6758	—	—	79·7040	—
—	—	$\frac{1}{3}$	11·3578	$\frac{1}{3}$	43·5586	—	$\frac{1}{6}$	13·2840	—

If the interval is other than unity, account must be taken of it, multiplying the sum for $\int y\,dx$ by the interval, and the sums for $\int xy\,dx$ and $\int y^2\,dx$ by the square of the interval.*

When the integration has to take place in two dimensions, as in calculating the displacement and mechanical centres of ships, a much greater saving can be effected by systematic arrangement.†

It is sometimes more convenient to compute the area of a curve from the polar expression $\int -\frac{1}{2}\,r^2d\theta$; but this needs no special remark.

The rectification of a curve is but a particular species of quadrature, being either $\int\sqrt{(dx^2+dy^2)}$ or $\int(\sec\phi.dx,)$ where ϕ is the angle between the tangent and the axis of abscissæ. Its arithmetical treatment presents no special feature, unless it be that the secant of ϕ has to be obtained from ordinates. This is fully treated of in Cap. IV. Sec. 6 of this report.

The quadrature of a curved surface by means of ordinates rests on a similar principle, namely, on the quadrature of the double integral $\iint\sec\phi\,dxdy$ where ϕ is the angle between the tangent plane, and the plane of the base (xy). The greater part of the work turns upon the determination of $\sec\phi=\sqrt{\left\{1+\left(\frac{dz}{dx}\right)^2+\left(\frac{dz}{dy}\right)^2\right\}}$. This done, the

* See some examples of integrations differently arranged for other purposes, in various papers in the *Transactions of the Institution of Naval Architects*—especially vol. ii. p. 163, vol. v. p. 9, vol. vi. p. 51.

† For examples of a 'displacement sheet' see *Shipbuilding, Theoretical and Practical*, by Napier, Rankine, Barnes, and Watts (Mackenzie) p. 46; and *Theoretical Naval Architecture*, by Thearle (Collins) pp. 50–58 and Table I. For a similar sheet suited to the application of Woolley's rule see *Trans. I.N.A.*, vol. viii. p. 213. Many other interesting examples of carefully arranged integration will be found scattered through the *Trans. I.N.A.* and treatises on naval architecture, such as Scott Russell's, and the works already quoted.

double integration is easily effected between the required limits, either by Woolley's rule, or by any other method which may suit the case.*

It is of some consequence to conduct the work so that the degree of accuracy may be as nearly as possible the same throughout. It is best to follow the rule of using as nearly as possible the same number of significant figures right through. Thus it is idle to use five or six figures for a moment, and only two or three for the coördinate of the centre of gravity, because either there are more than we want for the moment, or else there are not enough if we require any further step to be taken from the value so found for the centre of gravity. It is a common thing to see much good work disfigured by want of attention to this. The rule above suggested is not absolute; but it is on the whole the best to work from, except in some special cases, which a little thought will easily discriminate.

It is scarcely necessary to enter into any detailed disquisition concerning the application of arithmetic to interpolations. Probably too much has already been written on the subject. With regard to interpolation in two dimensions, the reader may usefully consult Legendre, *Fonctions Elliptiques*, vol. ii. cap. xv. pp. 201–207.

IX.—Graphical Methods.

Of mere interpolation, there is no need to say anything here. When once a function is represented by the ordinate of a curve, the interpolation is effected at sight, whether the direct interpolation from the intermediate value of the variable, or the inverse operation of obtaining the value of the variable corresponding to a given value of the ordinate. In the same way a parallel ruler will give us the means of interpolating direction, and of finding maxima and minima.

In the case of quadrature there is something to be said, although that is very little more than the translation of the arithmetic into geometry. The geometry is practically restricted to the simple parabolic rule, or to the trapezoidal rule—the parabolas of higher order are of course unsuited to graphical work. That they are so has already been shown to be a matter of no great consequence.

The fundamental operation of quadrature is that of finding the area of a plane curve. It is convenient to reduce the construction to that of finding the area included between a base line, two parallel ordinates at right angles to the base, and a curved line forming a fourth side to the figure. As has been already remarked, this curve must never be parallel to an ordinate, nor should it have any abrupt curvatures.

If we work by the trapezoidal rule, we may divide the base into any number of intervals; if by the parabolic (or Simpson's) rule we must take an even number of intervals;—and in either case we draw ordinates through the points of division. Taking the simpler rule first—which is equivalent to assuming that the line joining the heads of two successive ordinates is straight—the sum of the first and second ordinates is set off on the second ordinate. This represents twice the area of the curve between those ordinates, which doubled area is a strip equal to the length so set off, and of the width of the interval between the ordinates. Twice the area between the second and third ordinates is similarly represented.

* An example of one arrangement for this purpose was given by the author in vol. vi. of the *Trans. I.N.A.* pp. 64–72, and also in Scott Russell's *Naval Architecture*, pp. 135–138. It is a cumbrous process at best.

by their sum. This, added to the length previously laid off on the first ordinate, gives the area up to the third ordinate, and is set off upon that, and so on. This gives the ordinates of a new curve,* which represents double the area of the first curve up to any given ordinate, original or interpolated. The curve passes through the foot of the first ordinate, because there is no area until that has been passed. If the curve is inconveniently tall, it must be reduced by dividing all the ordinates in the same ratio.

If the parabolic method is preferred, we divide the base into an even number of intervals, and draw ordinates. Join the heads of all the odd ordinates by right lines cutting the even ordinates (produced if necessary) and divide the portion of the even ordinates included between the curve and the chord into three equal parts. Then the distance from the base to the point of division *nearest the curve* gives the area comprised between the adjacent odd ordinates. That is to say, it is the length of a strip, whose base is the double interval, and whose area is equal to that of the corresponding curved area. The length thus obtained on the second ordinate, is set off on the third: the length similarly obtained on the fourth ordinate is added to that on the second, and the joint length laid off on the fifth. We thus obtain ordinates for a curve of areas; only the scale is one-fourth of what would be obtained by the previous process applied to the same curve.

It is very important to keep an accurate account of the scale. This is best written along each curve: thus

curve of lengths, one inch representing	(say)	2 feet
curve of areas, one inch representing	,,	8 square feet
curve of volumes, one inch representing	,,	8 cubic feet
reduced curve of volumes, one inch =	,,	128 cubic feet.

The additions are best performed by setting off the lengths in succession on a straight-edged strip of paper. If only the total area is required, the whole operation can be performed upon the strip.

If moments are required, the first thing is to construct a curve representing the moments of the ordinates. Start from the foot of the first ordinate (whose moment about itself is zero), take the head of the second ordinate, double the third, treble the fourth, and so on. Integrate the curve thus obtained, and we get a curve of moments, any ordinates of which represent the moment of the area of the original curve up to that ordinate—the moment being taken about the first ordinate.† The moment may, of course, be taken about any other ordinate; but the new ordinates on one side of the selected ordinate must be set off below instead of above the base. The scale may be reduced at the first operation by taking the multipliers 0, n, $2n$, $3n$, $4n$, &c., where n is a fraction, instead of using 0, 1, 2, 3, 4, &c.

If the curve of areas be again integrated from the foremost end, the complete integral represents the moment of the original curve about the final ordinate. This is a consequence of the formula (easily obtained by integrating by parts)

$$x\int y\,dx = \iint y\,dx\,dx + \int xy\,dx$$

* See chapter vi. for some observations on the mode of drawing these curves.

† The moments must be taken about an ordinate, not about the base. If moments about the base are wanted, a fresh set of ordinates must be taken parallel to the base.

The interval used in the graphical process is quite immaterial provided careful account be kept of scale. It is impossible to pay too much attention to this point.

It is, of course, not necessary that the original ordinates should represent lengths. They may represent areas, in which case their curve of areas will represent volumes; or they may represent pressures, in which case, with a suitable interpretation of the interval, the areas will represent work; or, again, the integral of a curve of temperatures may represent heat. Whether it actually does so, or not, depends upon what is taken for the interval.

What all these processes effect is mere summation with suitable coefficients. The processes of multiplication or division, except by a small integer, are not conveniently performed in this way. So, although we get out the moments graphically, we must have recourse to arithmetical division, to find the position of the centres of gravity, or of gyration. Similarly, if we want to set off the squares, or the cubes, of the ordinates, we must use a table of squares or cubes, and set off from that.

It is best to use printed or lithographed sheets divided into squares, the interval being chosen with reference to the work to be done. In English shipbuilding work, which is usually drawn on a scale of $\frac{1}{4}$-inch to the foot, quarter-inch squares are the most convenient. There should be a thicker rule at every fifth or tenth line, to prevent mistakes in counting. Any sized square will do, only if the right size be chosen, it saves, at least, one set of reductions. For mere quadratures, it is not necessary that the lines should be exactly at right angles, but in cross-measurements it is inconvenient to have the two diagonals measuring different lengths.

The intersections of curves drawn to the same scale solve graphically a number of equations, differential and other, which it would be difficult to treat otherwise. There is no difficulty in changing the independent variable. One of the simplest ways of doing this is by the interchange of x and y, by taking a fresh set of ordinates at right angles to the old ones. But as there is no restriction to rectangularity, and as we may measure to an inclined or even a curvilinear base, it is obvious that the range of transformation is very wide indeed. An example of the application of this to the problem of rectilinear motion in a resisting medium will be found in the 'Phil. Mag.' for June, 1868. Neither of these points, however, falls strictly within the scope of this report, and therefore it is unnecessary to enlarge upon them.

As regards the accuracy of these graphical methods, the work in the Royal School of Naval Architecture was generally done from drawings on a scale of $\frac{1}{4}$-inch to the foot. The displacement got out correctly in two ways used generally to agree within about $\frac{1}{4}$ per cent. If it exceeded $\frac{1}{3}$ per cent., it used to be regarded as evidence of a blunder. As regards blunders, graphical processes have the advantage of making these apparent by a corner in the curves.

Polar quadrature of an area.—It was pointed out to the author by the late M. Normand of Havre, that the polar quadrature could be very rapidly applied to finding the area of transverse section of a ship's hold. For this purpose the angles could be marked on a wooden quadrant held vertically athwartships at the corner underneath a deck, and divided into equal angular intervals, while a tape would pass from the centre of the

quadrant to the opposite side or bottom of the ship and would be made to cover one of the divisions. The observed length of this tape being r, the integral $\int \frac{1}{2} r^2 d\theta$ would give the area. The work might be still further shortened by graduating the tape according to $\frac{1}{2} r^2$ instead of by equal divisions. There would then remain nothing but the quadrature.

This method might be conveniently applied geometrically in the case of curves having two axes of symmetry, like the ellipse, to which parabolic quadrature is not applicable. This is, however, only one of a very great number of the possible transformations of the independent variable.

Length of a curve.—Draw a chord between its extreme points, divide the chord into equal parts and draw ordinates at the points of division, at right angles to the chord. Draw tangents to the curve where these ordinates cut it, and let these tangents be produced both ways to meet the ordinates at the extremities. Use the lengths of these tangents as ordinates, and integrate them by any method of quadrature, dividing by the number of ordinates. The result will be the length of the curve.*

Curved Surface.—The only general method of dealing with this is first to construct, and then to integrate between the requisite limits, sec $\phi\, dx\, dy$, where ϕ is the angle between the tangent plane and the base, or plane of (x,y). The construction of the term sec ϕ for any given point is easy enough, since this is simply the through diagonal of a parallelopiped, of which the base is given, and the directions of the diagonals of faces are also given. The number of ordinates, however, for which this calculation has to be made is large, being in two dimensions, and there is then a double integration to be performed. Moreover the limits are not necessarily or usually constant, and then again the methods fail where the surface is parallel to an ordinate, and in either of these cases the surface has to be specially cut up, presenting in reality several different pieces of work. All this renders it a very laborious task, and unfortunately the integral for the surface does not present any such reductions, when treated by ordinates, as the volume-integral.

In iron shipbuilding, when the work is complete, and a separate account is taken of every plate, the weight of skin and area of the surface are of course mere matters of addition. But while the design is in draft, it sometimes becomes necessary to estimate the surface in a more summary manner. The usual mode is to obtain the lengths of all the level lines and transverse sections of the surface, and then to expand the surface on the flat by means of two sets of strips of paper, which secure equal lengths for the sides of the quadrilaterals, the angles being allowed to take up their own adjustment. This is a very coarse representation, even supposing the expansion to be split where the distortion is great, as it usually is where the skin of a ship meets the sternpost. This process is occasionally modified by using an orthogonal network on the surface, instead of orthogonally dividing the plan, and that is probably a little better. Another more accurate plan has been given by Mr. Crossland † of the Admiralty. A model of the ship is usually more convenient to work from

* This method is given by Rankine in his *Rules and Tables*, p. 75. It is nothing more than the graphical quadrature $\int$ sec $\phi\,.\,dx$.

† See the *Annual of the Royal School of Naval Architecture* (for 1873) pp. 12–14.

than drawings, although it is quite possible to get the constructions without much difficulty from these. Nevertheless, it is a laborious and unsatisfactory process, and quite inapplicable to complex or highly curved surfaces. It does, however, give a rough approximation, and, as such, is found both useful and necessary by shipbuilders.

X.—Mechanical Quadratures.

Rectification.—The only satisfactory mechanical means of doing this is by running a wheel along the curve, and observing its travel. In the *opisometer* it is done by starting the wheel from a stop, running it along the path to be measured, and then applying it to the scale of the map or diagram, and running it backwards until the stop is felt. This saves the trouble of any readings, except the final one upon the scale, and it also avoids all conversion of scale. It may be objected to it that it is a little wanting in minute accuracy, from a small yielding at the stop giving a considerable error at the edge of the wheel. This, however, can easily be tested on a plain scale, and careful use of the instrument with a delicate hand gives very good results.

There is a more elaborate but very convenient form of the machine sold under the curious name of 'Wealemefna.'

Direct mechanical quadrature.—If a disk revolve at uniform velocity, and a friction wheel roll upon it, having its axis parallel to the plane, and meeting the axis of the disk, then it is clear that the travel of the friction wheel will be directly proportional to its distance from the centre of the disk. If, therefore, the friction-wheel be made to slide upon the disk, so that its point of contact shall be separated from the centre by a distance equal to the varying ordinate of a curve, while the disk rolls along a straight line base, the travel of the friction-wheel will integrate the area of the curve. This is the simplest mechanical integrator there is. It is used in one form as the 'continuous indicator' in steam-engines, and in another form it is used for integrating the curves of the German tide-gauges. It is also used in the recording part of Morin's dynamometer, and in Sang's planimeter.

James Thomson's integrator.—This ingenious instrument was devised in order to get rid of the sliding which takes place in the continuous integrator, and in Amsler's planimeter. It consists of a plane circular disk inclined at an angle of 45° to the horizon, and turning freely on an axis normal to its plane. A cylinder with its axis horizontal and parallel to the plane of the disk is mounted on journals in front of the disk, so that they just clear one another. A smooth sphere is dropped into the trough between the disk and the cylinder, and the machine is so adjusted that the sphere can just roll over the centre of the disk. The amount of rotation of the cylinder as the disk turns through a given angle, will vary as the distance of the point of contact of the sphere and disk from the centre of the latter. The travel of the sphere laterally is obtained by means of a fork, which is made to slide in the direction of the axis of the cylinder, and which nips the sphere between two pads or cushions, on which it slips easily. If now a flat templet with a straight base and a curved edge opposite the base, is moved in the plane of the disk and at right angles to the axis of the cylinder, so that the disk, or a pinion in gear with it, rolls along the base, while a pin in the fork-handle

follows the curve on the other side of the templet, the travel of the cylinder will effect the quadrature of the curve on the templet.*

The use of the machine is by no means limited to this simple quadrature. By putting the fork in gear with the disk through the intervention of suitable wheel or link-work, or belting; or by gearing two such machines suitably together, it is possible to obtain the mechanical solution of differential equations.†

Sliding motion is not altogether escaped in this machine. In the first place, there is sliding motion of the sphere in the fork. Further, the rolling of the sphere along a small circle is not pure rolling, but, although not having any actual sliding, is intermediate between sliding and rolling. For if we separate the pure rolling along a great circle from the twist necessary to make it describe a small circle, the aggregate of this twisting is the same as we should get by turning the sphere through a definite angle about an axis perpendicular to the disk; but instead of being finite sliding, as it would be on this last supposition, it is in fact distributed over a line instead of concentrated at a point. It is thus infinitesimal at every point of the line, along which, however, there ceases to be pure rolling.‡

There is also a source of error in the necessity of giving some clearance to the fork, which would otherwise not slide on the sphere. This clearance introduces a slight error every time the fork reverses its motion. It is, however, a constant error; but it is always in the same direction, and is not compensated on a double reciprocation. This is the chief drawback to the machine, which is nevertheless a most valuable instrument.

Amsler's planimeter.—In this wonderful little instrument a pointer is made to run round the closed curve, which has to be measured, and a little wheel, which partly rolls and partly slides, gives the area by the mere reading of its rolling motion. The main principle on which it depends is this: that if a finite right line moves in its own plane, the whole area swept out by it is measured by the product of the length of the line, and by the sum of the components of the motion of the middle point (resolved at every instant) at right angles to the line. A wheel turning on an axis parallel to the line, and free either to roll or to slide on the paper or plane, will effect this instantaneous resolution, and its reading will integrate the required component. When one end of the bar makes a complete circuit of a closed curve, coming back to the point from which it started, while the other end reciprocates along an arc of any fixed curve, wholly external to the closed curve, the area of the latter is given by the difference between the initial and final readings of the wheel. In this case, moreover, the principle of the separation of the motions of rotation and translation shows that the total reading of the friction wheel will be the same, if it be moved from the middle to any other point of the line, or even of the line produced. The only adjustment required, therefore, is that the axis of the rolling wheel should be parallel to the bar which carries the pointer. This freedom from adjustment is one of the most valuable properties of the instrument. As a practical matter, the accuracy of the results which it gives is quite equal to that of the very best drawings which can be made.

* See *Roy. Soc. Proceedings*, vol. xxiv. p. 262, 'On an Integrating Machine having a new Kinematic Principle,' by Professor James Thomson.

† See two papers by Sir Wm. Thomson at pp. 266 and 269 of the same volume.

‡ The motion is intermediate, in much the same sense that $x^a (\log x)^b$ is intermediate in dimension to x^a and x^{a+k}. See De Morgan's *Diff. and Int. Calc.* p. 323.

In the usual form of the instrument, the reciprocating curve, traced by the other end of the bar, is an arc of a circle. This is for facility of use and construction, and is by no means essential.

Amsler's Mechanical Integrator.—By an ingenious extension of the principle of his planimeter, Professor J. Amsler-Laffon, of Schaffhausen, has constructed a machine which, while a pointer describes a closed curve, records simultaneously its area, its statical moment, and its moment of inertia about a given axis. In this case the butt end of the bar which carries the pointer is made to move along a right line. The area is read off from a wheel mounted on the bar itself, and this part of the operation is thus the same as in the common planimeter. The moments are read off from wheels mounted on arms whose centres also describe right lines, but which are so geared with a wheel rigidly connected with the bar carrying the pointer, as to turn relatively to it with the fixed velocity ratios of 2 : 1 and 3 : 1. Supposing the angular motion of the pointer-bar to be θ, and the velocity ratio $n : 1$, the quantity of rotation of the second circle will be $n\theta + \alpha$, α being an arbitrary constant depending upon the initial position. When the pointer goes round any closed curve which does not contain the centre of the first circle, this measurement of this rotary motion comes to nothing, for the angular movement is the same forward as backward, and it may therefore be left out of account. But its angle $(n\,\theta + \alpha)$ settles the direction of the resolution of which the component is measured by the instrument, when there is linear motion of the centre. The rolling wheel records a constant multiple of

$$-\,dx \cos\,(n\,\theta + \alpha),$$

where dx represents the movement parallel to the axis, and its complete record is

$$-\int dx \cos\,(n\,\theta + \alpha) = -\,u$$

taken over the whole *area* of the curve. This has to be multiplied by a numerical factor, which is one of the constants of the instrument.

Where $n = 2$, if we make $\alpha = 0$, we have

$$u = \int dx \cos 2\,\theta = \int dx \left\{1 - 2\,(\sin\theta)^2\right\} = \int dx \left(1 - 2\,\frac{y^2}{k^2}\right)$$

y being an ordinate perpendicular to the axis of x.

In this case therefore the difference between two readings of the rolling wheel counter is always proportionate to $\int y^2\,dx$, which thus gives the statical moment.

When $n = 3$, if we make $\alpha = -\frac{1}{2}\pi$,

we have

$$\cos\left(3\,\theta - \frac{1}{2}\pi\right) = \sin 3\,\theta = 3\,(\sin\theta)^3 - 4\sin\theta$$
$$= 3\,\frac{y^3}{k^3} - 4\,\frac{y}{k}$$

and therefore the reading given by the wheel is

$$\int a y^3\,dx - \int by\,dx$$

that is to say, it gives the difference between a fixed multiple of the moment of inertia and a fixed multiple of the area. In this way the moment of inertia is known. The subtraction is not performed by the machine, but is left to the calculator.*

Sang's planimeter is described and figured in a paper by Mr. Sang in the 'Transactions of the Royal Scottish Society of Arts' for 1852, vol. iv.

There is also a paper by Mr. Clerk Maxwell in the same 'Transactions' (for 1855, vol. iv.) describing a planimeter invented by himself, and the action of which depends on the mutual rolling of two equal spheres.

These are the principal mechanical integrators known to the author. So far as a draughtsman's purpose is concerned, Amsler's instruments appear to be the most convenient practically.

The French Deep-sea Exploration in the Bay of Biscay. *By* J. GWYN JEFFREYS, *LL.D., F.R.S.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

I FEEL that I am indebted for the opportunity of giving an account of the French expedition, which forms the subject of this paper, to my esteemed friend and colleague, the Marquis de Folin, of Bayonne. He was until lately the commandant of that port, and is a most zealous and excellent naturalist. I may, indeed, say that the expedition originated with him. For more than ten years he had, at his own expense, assiduously and carefully explored the sea-bed lying off Cape Breton, in the Department of the Landes, as well as could be done in a fishing-boat; and the result of his researches among the marine Invertebrata has been described, with illustrations by his pencil, in a useful work called 'Les Fonds de la Mer,' published at Bayonne under his direction. M. de Folin has from time to time sent me the Mollusca procured in his dredgings for my opinion; and our correspondence, with a visit which I paid him in December 1878, led to his making an application to the French Government for the grant of a vessel to explore the depths which were known to exist at a comparatively short distance from the northern coasts of Spain in the Bay of Biscay. This evidently could not be done in a fishing-boat; and naturalists have much less money than science. It was, in fact, a project for a nation, and not for an individual. The application was, I believe, referred to the Dean of the Academy of Sciences, M. Milne-Edwards, whose reputation as an eminent zoologist has been universally recognised for more than half a century. His report was favourable; and a Government vessel was ordered to be placed at the disposal of a Commission of which M. Milne-Edwards was appointed President. The other members of the Commission were the Marquis de Folin, Prof. Alphonse Milne-Edwards, Prof. Vaillant, Prof. Marion of Marseilles, Dr. Paul Fischer, and M. Périer of Bordeaux. The selection of these savants

* A detailed description and drawings of the machine is given in the volume of the *Transactions of the Institution of Naval Architects* for 1880. It will not escape the reader that this machine requires several rather nice adjustments which are not needed in the common planimeter. The machine, as actually made for sale by Mr. Amsler, is very beautifully contrived, with regard to all its mechanical details, and it works very smoothly and satisfactorily. The cost is between £16 and £20.

augured well for the success of the expedition, and it has been fully justified. At the suggestion of M. de Folin, the Minister of Public Instruction graciously invited me and the Rev. A. M. Norman (a well-known naturalist) to take part in the expedition. Mr. Norman had been my valued companion for many years past in similar but less important excursions to Shetland and Norway. It was to me a great pleasure to be again associated with him. I regarded the invitation as far more than a compliment; it was a great honour.

I may here mention that, immediately before the commencement of the expedition, M. de Folin, Mr. Norman, and myself had some preparatory boat-dredging in the Fosse de Cap Breton. This was done at the expense of the French Government. When has our own Government shown such generosity in the cause of science to French naturalists?

The vessel assigned for the purposes of the expedition was the *Travailleur*, a paddle-wheel steamer of over 900 tons, of 150 horse-power, and carrying four guns. She is an *aviso*, or despatch-boat, and is stationed at Rochefort for occasional service. She was supplied with a capital donkey-engine, and immense stores of cordage, sounding-wire, and other apparatus. She had a very happy name, being an indefatigable worker. Capt. E. M. F. Richard was the commander, or *lieutenant de vaisseau*, and the other officers were Lieuts. Mahieux, Jecquet, Villegente, and Bourget, Aide-Commissaire Gousselin, and Dr. Duplouy. Let me now express my sincere thanks to the officers for their great kindness and urbanity. They took a great interest in the work, and materially promoted the welfare of the expedition. The crew consisted of 128 men; the usual number was between 80 and 90, but extra hands were taken in consequence of the heavy work entailed by sounding during the night. All these men seemed to be well-conducted, as well as good sailors; and, although they had only two meals a day, their physique was quite equal to that of our best British seamen. Mr. Norman and I took with us, as dredger, a steady and intelligent man, John Wilson; and Prof. Marion had his dredger named Armand. These men were of great use in sifting the material brought up by the dredges. For the captain, I can only echo the opinion expressed by Prof. A. Milne-Edwards in his preliminary Report, that his arrangements were first-rate, and his skill admirable, especially considering that the kind of work was new to him, and that he had not previously made or even seen any deep-sea dredging.

The members of the Commission assembled at Bayonne; and the *Travailleur* arrived there on the 16th of July. The next morning she went to sea, with all the party on board except the President, who was obliged to return to Paris, and might also have justly claimed exemption from active service, being in his eightieth year. Until the 1st of August (with the exception of two days, the 18th and 25th, which we spent at San Sebastian and Santander,) we were hard at work sounding, dredging, and trawling. The weather was very fine, and the dreaded Bay of Biscay lost its stormy character on this occasion.

The principal object of the expedition was to ascertain the nature of the fauna which inhabits at considerable depths this part of the Bay of Biscay; and this object was thoroughly and successfully accomplished. Twenty-three dredgings were made for that purpose at depths ranging from 337 to 2600 mètres, each mètre being about 39 inches, or rather more than half a fathom. The dredgings between 600 and 1000 fathoms were the most important. Every department of the Invertebrata was

well represented, and novelties were discovered in the Mollusca, Crustacea, Echinoderms, Annelids, Actinozoa, and Sponges.

As regards myself, this expedition had a peculiar charm. Having had the scientific charge of similar expeditions for the Royal Society in H.M.S. *Porcupine* in 1869 and 1870, and in H.M.S. *Valorous* in 1875, and having examined the collections made during the voyages of H.M.SS. *Shearwater* and *Challenger*, as well as those made in nearly all the Swedish, Norwegian, Dutch, and American deep-sea and exploring expeditions in the North Atlantic, I was naturally glad to participate in the French expedition, and particularly as it embraced that part of the sea which was at no great distance from the scene of my former labours in the cruise of the *Porcupine* along the western coasts of Spain and Portugal, and which cruise was so unusually productive. Impelled by this recollection, I made last year a verbal and informal application to the late First Lord of our Admiralty, for the use of one of her Majesty's ships to explore the Bay of Biscay this summer. The answer I received was very favourable; but the pecuniary resources of our Government were then at a low ebb, and I was encouraged to renew the application when commerce revived and times became more prosperous. I hope our new Government will avail itself of the now improved finances, and not neglect this genuine and beneficial method of instructing the nation, and maintaining its credit for maritime discovery.

The fauna observed during the *Travailleur* cruise closely resembled that which I ascertained during the *Porcupine* cruise of 1870 at corresponding depths. This will be shown, so far as the Mollusca are concerned, in the list of species appended to the present paper; and I have no doubt that the other branches, when they have been worked out by the experienced naturalists to whom they have been entrusted, will confirm my opinion.

In a physical and geological point of view this French expedition has borne good fruit. No less than 103 soundings were made. They have proved the existence, within a few miles of the coast, of a submarine valley opening from the Fosse de Cap Breton and extending to a point opposite Cap Peñas. The large diagram and chart which I now exhibit will give a better explanation than I can do by any words. The diagram was prepared for me when I presented to the Royal Society my reports of the *Porcupine* expeditions of 1869 and 1870; and the chart has been filled up and given to me by my kind friend the Hydrographer.[1] The striking inequalities of depth within a narrow area which thus appear were noticed in a Bayonne newspaper of August 4 as 'des grands fonds sous-marins, qui continuent sous les eaux de l'Atlantique les vallées pyrénéennes.' As a general rule, it may be said that where mountains or high land approach the sea the depth of water is greater off that coast than where the land lies low. But this must depend in a great measure on the geological nature of the land adjacent to the sea. If the formation be granitic or gneissic, the wear and tear or denudation must be slower than if the formation be sandstone, cretaceous, or tertiary; and the action of rivers and streams on the surface of the land must be proportionably increased or diminished, and cause the sea-bed to be more or less filled up in the course of time. Everywhere during the dredgings of the *Travailleur* in deep water the sea-bed was found to be covered by a thick layer of mud, of a different colour from

[1] See *Proceedings of the Royal Society* for 1870, and the Admiralty Chart of the Bay of Biscay.

that of the Atlantic ooze; and this mud has probably accumulated from untold ages by the incessant efflux of the Gironde, the Adour, and numerous other rivers and streams into the Bay of Biscay. As may be supposed, the fauna which inhabits such mud is very scanty; and it required a considerable amount of patience and perseverance to extract even a few organisms from the unpromising material. No wonder that Dr. Carpenter was discouraged, as a zoologist, by what he termed 'the singular barrenness of this deposit in regard to animal life,' when he described the Mediterranean cruise of the *Porcupine* in 1870.

Within a few days after the return of the expedition, Prof. A. Milne-Edwards presented to the Academy of Sciences at Paris a preliminary report of the zoological results of the expedition, which was published in the *Journal Officiel de la Republique Française* as well as in the *Comptes Rendus.* As most of the departments of the marine Invertebrata have been so fully and carefully treated by him in this Report, I will content myself with a few supplementary remarks as to the Mollusca, which especially engaged my attention during the cruise. At the request of Dr. Fischer, who will undertake this department, and with the sanction of the President, I was entrusted with all the more critical specimens of Mollusca; and these specimens I have now cleaned, assorted, and compared with my own collection from the *Porcupine* Expedition of 1870 on the western coasts of Spain and Portugal. I subjoin a complete list of the *Travailleur* Mollusca, distinguishing in separate columns those species which are *Porcupine,* those which were previously known to me from Norway or the Mediterranean only, and those which I consider new to science. The total number of the species in this list is 198, out of which 169 are *Porcupine,* nine only appear to be exclusively northern, one exclusively southern or Mediterranean, and seventeen new to science. Two of the *Porcupine* species are northern also. The results, especially in the last-mentioned category, are most noteworthy. They serve to show how little we know of the deep-water Mollusca, when we reflect that the area of the sea-bed lately explored, in a short period of time and in a necessarily cursory manner, is but a very small corner of the Atlantic, and that it would take many years to complete the exploration so auspiciously commenced. The space traversed by the dredge during this cruise represents probably much less than a ten-thousandth part of the sea-bed lying between Cap Breton and Cap Peñas; and our means of exploration by the dredge are by no means satisfactory, particularly on muddy ground, of which the deep water zone is mainly composed. Instead of our being able to scrape a few inches of the surface of the sea-bed at considerable depths, so as to collect in the dredge all the animals which inhabit the superficial layer, we find too often, to our disappointment, that the dredge when it reaches the bottom sinks into the mud from its own weight and from the momentum given to it by the motion of the ship, and that it then acts as a subsoil plough and not as a scraper. I must ask one of my engineering friends to devise some instrument more efficient than the modern dredge.

Although it cannot be positively stated that the abyssal zone, or even the benthal zone, is inhabited by species of Mollusca peculiar to it, some species observed by me during the preparatory excursion to Cap Breton and the *Travailleur* cruise bear out the statement to some extent. For instance, *Nucula nitida, Dischides bifissus, Rissoa abyssicola* (a now inappropriate specific name), and *Defrancia decussata* occurred only in the

shallow-water excursion, while *Nucula corbuloïdes*, *Siphodentalium Olivi*, *Rissoa deliciosa*, and *Defrancia hispidula* occurred only in the deep-water cruise.

The list of Mollusca will show that several species are supposed to have been drifted from shallow water. This may have been owing to the proximity of the coast and to the consequent action of rivers and tides.

Several deep-water species of Mollusca occurred in this expedition which had been until lately supposed to be extinct; they are fossils of the Upper Tertiaries of Europe.[1]

A curious provision of Nature—if we may in these philosophical days use such a phrase—was observable in the case of a deep-water mussel of considerable size, which I propose to name *Mytilus luteus*. It inhabits the layer of mud which I have above described, and moors or fixes itself by means of a large and densely matted byssus which is spun by the foot. This byssus is capable of being spread over a considerable extent of surface; and it not only prevents the mollusc sinking into the soft mud and being smothered or buried alive, but enables it to feed comfortably on the innumerable animalculæ which swarm on the surface of the sea-bed. It is to some extent of the same use to the mollusc as a snow-shoe is to the Arctic traveller. This species of *Mytilus* I at first took to be the *Modiola incurvata* of Philippi = *M. Martorelli* of Hidalgo—which lives on the south coast of Spain in rather shallow water; but on comparison I am satisfied that they differ essentially in shape, sculpture, colour, and epidermis.

I cannot conclude this account without tendering my most grateful acknowledgments to the French Government for their extremely generous conduct, and for the excellent hospitality which I enjoyed on board the *Travailleur*, as well as to the President and members of the Scientific Commission for their obliging and friendly companionship.

The zoological results of this French expedition are fully equal to those obtained by Capitaine Baudon in 1801, M. d'Urville in 1829, the *Recherche* in 1835, the *Bonite* in 1836 and 1837, the *Astrolabe* in 1841, and other expeditions; and I sincerely hope that a further expedition of the present kind may take place next year in the Mediterranean, where our good and gallant neighbours have such an important stake.

A List of the Mollusca procured during the cruise of the *Travailleur* in the Bay of Biscay, 1880.

No.	Name of Species	*Porcupine* cruise, 1870	Northern	Southern	New to Science	Remarks
	BRACHIOPODA.					
1	Terebratula caput-serpentis, Linné	—				See as to this and other Mollusca in the list the 'Proceedings of the Zoological Society of London' for 1878 and 1879.
2	T. subquadrata, Jeffreys					
3	T. cranium, Müller; a fragment	—				
4	Platydia anomioïdes, Scacchi and Philippi	—				
5	Megerlia truncata, L.	—				
6	Crania anomala, Müll.	—				

[1] For the geological definition of this term see *British Conchology*, vol. i. pp. 315 and 316.

LIST OF MOLLUSCA—*continued.*

No.	Name of Species	*Porcupine* cruise, 1870	Northern	Southern	New to Science	Remarks
	CONCHIFERA.					
7	Anomia ephippium, L.	—				
8	Spondylus Gussoni, O. G. Costa.	—				
9	Pecten pes-lutræ, L.	—				*P. septemradiatus*, Müll.
10	P. grœnlandicus, G. B. Sowerby	—				
11	P. fragilis, J.	—				
12	P. obliquatus, J. (MS.)				—	
13	P. vitreus, Chemnitz	—				And variety *abyssorum.*
14	Pecten similis, Laskey	—				A single valve; probably drifted.
15	Amussium fenestratum, Forbes.	—				And a monstrous variety.
16	A. lucidum, J.	—				
17	Lima elliptica, J.	—				
18	L. subauriculata, Montagu	—				
19	L. Jeffreysi, Fischer (MS.)				—	
20	Mytilus luteus, J. (MS.)				—	Allied to *Modiola incurvata*, Philippi = *M. Martorelli*, Hidalgo; but it differs in shape, sculpture, epidermis, and colour. Dr. Hidalgo agrees with me as to this.
21	Mytilus edulis, L.	—				A valve of a young specimen; probably drifted.
22	Modiolaria marmorata, Forbes.	—				Same remark.
23	M. subclavata, Libassi	—				
24	M. cuneata, J. (MS.)				—	
25	Dacrydium vitreum (Holböll) Müller.	—				
26	Arca pectunculoïdes, Sc.; var. septentrionalis.	—				
27	Arca lactea, L.	—				A single valve; probably drifted.
28	Leda messanensis, Seguenza	—				*L. acuminata*, J. (not Von Buch).
29	L. pustulosa, J.	—				
30	L. striolata, Brugnone	—				
31	L. tenuis, Ph.	—				*L. pygmæa*, auct., not v. Münster.
32	L. lucida, Lovén	—				And a variety.
33	L. pusio, Ph.	—				And variety *latior.*
34	L. sericea, J.	—				
35	L. Jeffreysi, Hid.	—				*L. lata*, J. (not Hinds).
36	L. expansa, J.	—				
37	Nucula ægeensis, Forb.	—				
38	N. corbuloïdes, Seg.	—				
39	N. striatissima, Seg.	—				
40	N. tumidula, Malm	—				
41	N. sulcata, Bronn	—				
42	Limopsis cristata, J.	—				

LIST OF MOLLUSCA—*continued.*

No.	Name of Species	*Porcupine* cruise, 1870	Northern	Southern	New to Science	Remarks
43	L. minuta, Ph.	—				
44	Malletia obtusa, M. Sars	—				
45	M. cuneata, J.	—				
46	Montacuta ferruginosa, Mont.	—				
47	M. tumidula, J.					
48	M. ovata, J. (MS.)	—				
49	Decipula ovata, J.	—				
50	Kellia symmetros, J.		—			*Valorous* Expedition, 1750 fathoms; Norwegian Arctic Expedition, 656 and 1200 fathoms.
51	Lasæa rubra, Mont.	—				A single valve; probably drifted.
52	L. pumila, S. V. Wood	—				A Coralline Crag fossil.
53	Loripes lacteus, L.	—				Probably drifted.
54	Axinus flexuosus, Mont.	—				
55	A. croulinensis, J.	—				
56	A. eumyarius, M. Sars.	—				
57	A. ferruginosus, Forb.	—				
58	A. subovatus, J.	—				
59	A. granulosus, J.	—				
60	A. tortuosus, J. (MS.)				—	
61	Mytilimeria? Fischeri, J. (MS.)				—	
62	Cardita corbis, Ph.	—				
63	Cardium minimum, Ph.	—				
64	Isocardia cor, L.	—				And the fry, which has many synonyms.
65	Woodia digitaria, L.	—				A single valve; probably drifted.
66	Tellina gladiolus, J. (MS.)				—	
67	Scrobicularia alba, W. Wood	—				
68	S. longicallus, Sc.	—				
69	S. nitida, Müll	—				
70	Lyonsia formosa, J. (MS.)	—				
71	Verticordia insculpta, J. (MS.).	—				
72	Thracia convexa, W. Wood	—				Young.
73	T. tenera, J. (MS.)				—	
74	Neæra abbreviata, Forb.	—				
75	N. rostrata, Spengler	—				
76	N. cuspidata, Olivi; var.	—				
77	N. bicarinata, J. (MS.)	—				A fragment.
78	N. sulcifera, J. (MS.)	—				
79	N. truncata, J. (MS.)	—				
80	N. lamellosa, M. Sars	—				
81	N. striata, J.	—				
82	N. imbricata, J. (MS.)	—				
82*	Panopea plicata, Mont.	—				
83	Saxicava rugosa, L.	—				
	SOLENOCONCHIA.					
84	Dentalium striolatum, Stimpson.	—				*D. abyssorum*, M. Sars; and variety *agilis*.
85	D. capillosum, J.	—				Fragments.
86	D. gracile, J.	—				Not *D. filum*, G. B. Sowerby, jun.

LIST OF MOLLUSCA—*continued.*

No.	Name of Species	*Porcupine* cruise, 1870	Northern	Southern	New to Science	Remarks
87	Siphodentalium lofotense, M. Sars.	—				
88	S. Olivi, Sc.	—				
89	S. tetragonum, Brocchi . .	—				*Dentalium quinquangulare*, Forb. = *S. pentagonum*, M. Sars.
90	Cadulus semistriatus, J. (MS.) .				—	
91	C. tumidosus, J.	—				
92	C. artatus, J. (MS.) . . .	—				
93	C. ovulum, Ph.					A Calabrian and Sicilian fossil.
94	C. gibbus, J. (MS.). . . .	—				
95	C. propinquus, G. O. Sars . .		—			
96	C. subfusiformis, M. Sars . .		—			
97	C. gracilis, J.		—			
98	C. cylindratus, J. . . .	—				
	GASTROPODA.					
99	Chiton alveolus, G. O. Sars .		—			
100	Rimula asturiana, J. (MS.) .				—	Probably *R. radiata*, Libassi, a Sicilian fossil.
101	Cyclostrema sphæroideum, S. V. Wood.	—				A Coralline Crag fossil.
102	C. trochoïdes, J.	—				
103	Mölleria costulata, Möller .		—			
104	Trochus gemmulatus, Ph. . .	—				A Sicilian fossil.
105	Turbo filosus, Ph. . . .	—				A Calabrian and Sicilian fossil = *Trochus glabratus*, Ph.
106	Hela tenella, J.	—				
107	Rissoa cimicoïdes, Forb. . .	—				
108	R. abyssicola, Forb . . .	—				
109	R. deliciosa, J. (MS.) . .	—				
110	R. subsoluta, Aradas. . .	—				
111	R. parva, Da Costa . . .	—				A dead specimen; probably drifted.
112	R. semistriata, Mont. . .	—				Same remark.
113	R. tenuisculpta, J. (MS.) . .	—				
114	Hydrobia ulvæ, Pennant; var. Barkei	—				
115	Scalaria Trevelyana, Leach .	—				
116	S. clathratula, Adams . .	—				
117	S. Cantrainei, Weinkauff . .	—				
118	Aclis Walleri, J.	—				
119	Odostomia conoïdea, Brc. .	—				
120	O. Lukisi, J.	—				
121	O. prælonga, J. (MS.) . .	—				
122	O. acicula, Ph.; var. obeliscus .	—				
123	O. blandula, J. (MS.) . .				—	
124	O. nana, J. (MS.) . . .	—				
125	O. insculpta, Mont. . . .	—				Probably drifted.
126	O. nitidissima, Mont. . .					Same remark.
127	O. sceptrum, J. (MS.) . .				—	
128	O. lineata, J. (MS.) . . .				—	
129	O. paucistriata, J. (MS.) . .	—				

LIST OF MOLLUSCA—*continued.*

No.	Name of Species	*Porcupine* cruise, 1870	Northern	Southern	New to Science	Remarks
130	O. fasciata, Forbes	—				
131	O. scillæ, Sc.	—				
132	O. plicatula, Brc.	—				*Turbonilla speciosa*, H. Adams.
133	Ianthina exigua, Bruguières	—				Brought by Gulf Stream
134	Eulima stenostoma, J.	—				
135	E. pyriformis, Brugn.	—				
136	E. subangulata, J. (MS.)	—				
137	E. solidula, J. (MS.)	—				And a fragment of perhaps a new species.
138	E. intermedia, Cantraine	—				
139	E. obtusa, J. (MS.)	—				
140	E. distorta, Dishayes	—				
141	E. curva, J. (MS.)	—				
142	Natica sordida, Ph.	—				*N. fusca*, de Blainville, may be either this species or a variety of *N. millepunctata*.
143	N. subplicata, J. (MS.).	—				
144	Solarium pseudoperspectivum, Brc.	—				*S. discus*, Ph.
145	Adeorbis umbilicatus, J. (MS.).				—	
146	Sequenzia, elegans, J.	—				
147	Lamellaria perspicua, L?	—				Or perhaps a distinct species. Adriatic (Stossich).
148	Aporrhaïs serresianus, Michaud	—				
149	Cerithium metula, Lov.	—				
150	Buccinum Humphreysianum, Bennett.	—				
151	Ranella gigantea, Lamarck	—				
152	Trophon muricatus, Mont.	—				
153	T. rugosus, J. (MS.)	—				And a fragment of perhaps another species.
154	Fusus gracilis, Da Costa	—				
155	F. turgidulus, J. (MS.)	—	—			Fragments.
156	F. berniciensis, King	—				
157	Cassidaria tyrrhena, Ch.	—				Perhaps a variety of *C. echinophora*, L.
158	Nassa semistriata, Brc.	—				
159	N. incrassata, Ström	—				
160	N. limata, Ch.; var.	—				
161	Columbella haliæeti, J.	—				
162	C. scripta, L.	—		—		A fragment of a young specimen; probably drifted.
163	Taranis cirratus, Brugn.	—				*Trophon Mörchi*, Malm.
164	Defrancia crispata, De Cristofori and Jan.	—				
165	D. parvula, J. (MS.)	—				
166	D. formosa, J. (MS.).	—				
167	Pleurotoma nivalis, Lov.	—	—			
168	P. pinguis, J. (MS.)	—				
169	P. modiolus, De Cr. and Jan	—				*P. carinata*, Ph.

LIST OF MOLLUSCA—*continued.*

No.	Name of Species	*Porcupine* cruise, 1870	Northern	Southern	New to Science	Remarks
170	Ringicula leptochila, Brugn.	—				
171	Cylichna umbilicata, Mont.	—				
172	C. ovata, J. (MS.)	—				
173	Utriculus expansus, J.	—				
174	U. obesus, J. (MS.)				—	
175	U. excavatus, J. (MS.)	—				
176	U. pusillus, J. (MS.)				—	
177	U. globosus, Lov.		—			A young specimen.
178	Actæon exilis, J.	—				
179	A. ovatus, J. (MS.)	—				
180	Bullina elongata, J. (MS.)				—	
181	Bulla pinguicula, J. (MS.)	—				
182	B. semilevis, J. (MS.)	—				
183	Scaphander punctostriatus, Mighels and Adams	—				*S. librarius*, Lov.
184	Philine scabra, Müll.	—				
185	P. striatula, J. (MS.)	—				Young.
186	P. quadrata, S. V. Wood	—				
187	P. catena, Mont.					A single specimen; probably drifted.
188	Melampus myosotis, Draparnaud.	—				Brought from the shore.
189	Carinaria mediterranea, Péron and Lesueur.	—				Pelagic.
	PTEROPODA.					
190	Limacina helicoïdes, J.	—				All these are Pelagic.
191	L. carinata, J. (MS.)	—				
192	Spirialis retroversus, Fleming	—				
193	Cavolina trispinosa, Pér. and Les.	—				
194	C. labiata, D'Orbigny	—				*Hyalæa inflexa*, Pér. and Les.
195	Clio pyramidata, Browne	—				
196	C. lanceolata, De Bl.	—				
197	C. cuspidata, Lam.	—				
	CEPHALOPODA.					
198	A sucker of a small Octopod					Pelagic.
		169	9	1	17	

Supplementary Paper by the Rev. A. M. NORMAN, *F.L.S.*

As might have been expected, many of the Crustacea obtained off the Portuguese coast by the *Porcupine* occurred in the North Spanish dredgings. Among these were *Dorhynchus Thomsoni*, Norman, *Amathia Carpenteri*, Norman, *Ebalia nux*, Norman, *Ethusa granulata*, Norman, *Pagurus tricarinatus*, Norman, *Munida tenuimana*, G. O. Sars, and *Apseudes spinosa*, Sars, and *grossimana*, Norman. The large Norwegian Brachyuran *Geryon tridens*, Kröyer, which was traced southwards by the

Porcupine to the entrance of the Bay of Biscay, was found to be the most abundant species within the bay, though in size greatly dwarfed as compared with Norwegian specimens. A *Thysanopoda*, probably *norvegica*, was taken several times abundantly, and was probably caught as the dredge approached the surface. The large, most remarkable, and blood-red Schizopod *Gnathophausia Zoëa*, Willemoes-Sahm, which was discovered in the *Challenger* Expedition near the Azores and off the coast of Brazil, delighted us with its beauty. Many undescribed species were met with. Pre-eminent among these were a new genus allied to *Dromia*;[1] a very curious new genus of *Galatheidæ*, which is blind, and has the eye-stalks converted into spine-tipped processes; a new *Palæmonid*, remarkable for having its carapace girt with a ring of spines; and a *Scalpellum*, apparently new.

Among the Gephyrea were two species recently described by Danielssen and Koren, from the Norwegian coast, and not hitherto found further south; the grand *Sipunculus priapuloïdes*, which is the largest and most interesting species of the genus known to me; and the curious little *Ochnesoma Steenstrupii*. This latter species I dredged last year in great abundance at the mouth of the Hardanger Fiord, Norway. A third Gephyrean obtained is also perhaps the *Phascolosoma squamatum* of the same authors.

In the Fosse de Cap Breton the curious Annelid, *Sternaspis thalassemoïdes*, Otto, which was formerly referred to the Gephyrea, was found abundantly.

Several examples of the much-disputed *Chætoderma nitidulum* were obtained. This is one of those animals which, exhibiting relationship to more than one class in almost equal ratio, becomes, by its somewhat intermediate characters, of special interest.

Only a single Polyzoon occurred. This was *Triticella Boeckii*, or an allied species. It was infesting the crab *Geryon tridens*, on which same host the species just named was discovered by Professor G. O. Sars.

There was a remarkable absence of Hydrozoa.

In no class is the collection finer than among the Actinozoa. Of Actinians not secreting a corallum there were a new *Palythoa* parisitic on the spines of *Cidaris papillata*; an *Actinia* (*Adamsia* ?), parasitic on an Isis; and two or three other things which were not recognised by us. Of corals there were *Caryophyllia clavus*; a *Flabellum* belonging to the *Flabellum apertum* group, in which the corallum is little or not at all compressed; a *Deltocyathus*, and *Lophohelia prolifera*. Of Gorgonian allies there were *Gorgonia verrucosa*, and at least two species of *Isis*, one of which was of considerable size, and when dredged at night was gorgeously phosphorescent, exhibiting a blaze of light. Of Virgularians there were many fine species, including two large forms of *Virgularia* (or closely allied genus); what appeared to be a *Scytalium* of very elegant form and bright red, widely separated fins; a genus which, from the curved, flaccid state of the polyparium, appeared to be devoid of all calcareous axis; *Kophobelemnon stelliferum*, and an example of the genus *Umbelluria*.[2] This genus, first discovered in the Arctic seas in 1753, and admirably figured by old Ellis, was lost sight of for 120 years, when it was rediscovered by Lindahl in the Swedish expedition between Greenland and Newfoundland.

[1] M. Alphonse Milne-Edwards had previously seen this among the Crustacea dredged by A. Agassiz in the *Blake*, and proposes to name it *Dioranodromia ovata*.

[2] Probably *U. Thomsoni*, Kölliker.

Subsequently the *Challenger* dredged it in several spots, and as far south as midway between Cape St. Vincent and Madeira. But the finding of this most interesting animal within a few miles of the European coast by *Le Travailleur* (July 30, in 1,160 mètres) leads us to hope that hereafter it may even be added to the British Fauna.

Echinodermata, as is usual in deep-sea dredgings, were numerous. Of *Holothuroidea* there was a form entirely unknown to me furnished with only two rows of suckers remarkable for their great size, and ten tentacula; a *Molpadia*, which has generally been regarded as an Arctic genus; and *Echinocucumis typica*, an abundant Norwegian type, of which the presence in the Bay of Biscay was evidenced by a single specimen. A curious instance occurred of the meeting in the Bay of Biscay of species hitherto supposed to be confined to Scandinavia with others regarded as eminently Mediterranean. The trawl had been down in 306 mètres, and when taken up out of it rolled one or two hundred huge Holothurians, each about a foot long. It was at once evident that they belonged to two species, and further examination proved about two-thirds of them to be the rosy-coloured *Holothuria tremula* of Norway, and the remainder, known at a glance by their light brown colour and flattened side, were *Stichopus regalis* of the Mediterranean. They had apparently met on this neutral ground, and were living together on the most amicable terms.

Sea Urchins were represented by *Echinus microstoma*, Wyville Thomson; *Calveria hystrix* (or an allied species), of which several fine specimens occurred; *Pourtalesia Jeffreysi*; and a new Spatangoid, remarkable on account of its globular form, and referable perhaps to the genus *Agassizia*.

Starfishes were not numerous in species, and gave us nothing new. *Archaster tenuispina* and *bifrons*, *Astropecter Andromeda*, and *Brisinga coronata* were the rarer forms.

The Brittle Stars were of much importance, for though the number of examples was not great the number of species, and perhaps of new forms, was considerable. The Ophiuridans require attentive study, and cannot be determined at a glance. It will suffice, therefore, to say that there were many which were not familiar to me, belonging apparently to the genera *Asteronyx* (parasitic on *Isis*, rather small, and possibly distinct from *Loveni*), *Ophiomusium*, *Ophiacantha*, *Ophioscolex*, together with a remarkably large and fine form which I was unable to refer to any genus known to me. An Ophiurid was also met with which I had discovered last year in Norway, and which I propose to name *Amphiura Danielsseni*.

Sponges, both with respect to the number of species and of specimens obtained, were scarce. *Thenea muricata*, Bowerbank (=*Wyvillethomsonia Wallichii*, P. Wright) and *Holtenia Carpenteri*, W. Thomson, only occurred in a young state; and a little bunch of the strong coarse spicula of the great *Askonema Setubalense*, Kent, came up wrapped round the dredging line; a single *Hyalonema Lusitanicum*, Bocage, was dredged in about 600 fathoms; and a fine, though dead, specimen of *Farrea* or *Lefroyella* was procured, though unfortunately in fragments.

The Foraminifera of course could not, from their minute size, be examined as they were dredged, but among the larger forms noticed in the sieves were many very interesting and recently described types. Foremost among these were the largest and most perfect examples of the beautiful *Orbitolites tenuissimus*, Carpenter, I had ever seen; they equalled a sixpence in size, and were dredged in about 1200 fathoms (July 20); and the very remarkable thread-like *Bathysiphon filiformis*, G. O. Sars,

which had, as far as I am aware, only before been met with in the Norwegian fiords. Arenaceous forms were abundant and fine, and included the following recently described species:—

Rhabdammina abyssorum, M. Sars.
Hyperammina ramosa, H. B. Brady.
Saccammina sphærica, M. Sars.
Psammosphæra fusca, Schultze.
Storthosphæra albida, Schultze.
Astrorhiza arenaria, Norman.
Lituola subglobosa, M. Sars.
Cyclammina cancellata, H. B. Brady.

In concluding these rough notes, I must express the deep sense I entertain of the kindness, courtesy, and attention which we received from the French naturalists who were members of the Commission, and also from Captain Richard and all the officers of *Le Travailleur*.

Third Report of the Committee, consisting of Professor Sir WILLIAM THOMSON, Dr. J. MERRIFIELD, Professor OSBORNE REYNOLDS, Captain DOUGLAS GALTON, Mr. J. N. SHOOLBRED (*Secretary*), Mr. J. F. DEACON, *and* Mr. ROGERS FIELD, *appointed for the purpose of obtaining information respecting the Phenomena of the Stationary Tides in the English Channel and in the North Sea; and of representing to the Government of Portugal and the Governor of Madeira that, in the opinion of the British Association, Tidal Observations at Madeira or other islands in the North Atlantic Ocean would be very valuable, with the view to the advancement of our knowledge of the Tides in the Atlantic Ocean.*

IN their last report the Committee requested, that the thanks of the Association be conveyed, to the First Lord of the Admiralty, the President of the Board of Trade, the French Minister of Public Works, the Belgian Minister of Public Works, to the several authorities and private individuals, both in this country and on the Continent, who have gratuitously aided in obtaining tidal observations for the Committee; and especially to the French Association for the Advancement of Science for the cordial support and assistance it has always afforded to the Committee in carrying out its task. As this recommendation came too late to be given effect to at the Sheffield Meeting, the Council during the past year, in its own name, performed this pleasing duty.

At the Sheffield Meeting, the further consideration of two points in particular was urged upon the Committee: 1st, the great utility of a recognised datum suitable for international observations, similar to the one made use of by the Committee; and 2ndly, the benefit likely to accrue to science, if the various maritime Governments, of Europe especially, were to arrange among themselves to carry out a lengthened series of tidal observations, and extending over a considerable area of coast.

The Committee, having carefully considered these points, and as they cordially agreed in them, urged the Council to press them upon the several Governments with whom they were communicating, respecting the labours of this Committee. It having also been pointed out, that, although the form in which the tidal observations as presented in last year's report (referred all to the English Ordnance Datum, and to Greenwich time) was most suitable for all observers on this side of the Channel, yet that it was hardly so for those on the Continent who had taken part in those observations, the Committee therefore decided upon reducing all the observations to the French official Datum of levelling and to Paris time. A pamphlet containing these tables, and prefaced by a special report in the French language, has been prepared for presentation to each of the foreign Governments, and observers on the Continent; and copies of it were transmitted through the Council with the thanks of the Association as above referred to. A copy of this document is appended hereto.

It is with much pleasure that the Committee have to report that the self-registering tide-gauge, which, at the instance of this Committee, the Board of Trade established on the Admiralty Pier at Dover, has been working, apparently with satisfaction, for nearly twelve months. A valuable series of tidal records may, therefore, now be commenced at this important station. This is highly desirable; and it is a measure which the Committee would strongly urge upon the Board of Trade. Seeing that similar self-registering records have been most carefully collected for some time back at Ostend, at Dunkerque, at Boulogne, and at Havre, on the opposite coasts; while on our own side, already, self-registering gauges exist at Sheerness, at Ramsgate, and at Portland.

The self-registering tide-gauge at Madeira, which the Portuguese Government, at the instance of H.M. Secretary of Foreign Affairs, acting on the request of this Committee, sent out to the Bay of Funchal, has been recently erected, and, it is understood, will soon be working satisfactorily.

The Committee beg to report that the sum of £10 has been expended in the preparation, printing, and distribution of the pamphlets to foreign observers. They request that the Committee be reappointed, with a grant of £10 to cover these expenses.

APPENDIX.

Rapport de la Commission chargée d'obtenir des Observations simultanées sur les Marées de la Manche et de la Mer du Nord, et des Renseignements sur le phénomène des Marées stationnaires qui ont lieu dans ces mers.

Les Membres de la Commission sont—Sir William Thomson (*Président*), *le* Dr. Merrifield, *le* Professeur Osborne Reynolds, *le* Capitaine Douglas Galton, *et* M. James N. Shoolbred (*Secrétaire et Rapporteur*).

Au Congrès de Plymouth, en 1877, une Commission a été nommée par l'Association Britannique dans le but indiqué ci-dessus; et aussi pour prier le Gouvernement Portugais, par l'intermédiaire du Gouvernement de sa Majesté Britannique, d'entreprendre un série d'observations sur les marées au Nord de l'Ocean Atlantique. Cette dernière demande a été

gracieusement accordée par le Gouvernement Portugais ; et afin d'obtenir les observations d'une manière regulière, un marégraphe enregistreur (système de Sir W. Thomson) a été installé dans la Baie de Funchal des Iles de Madère.

Avant d'entreprendre des observations simultanées dans la Manche et la Mer du Nord, la Commission s'est adressée, par les soins de son secrétaire, aux membres de l'Association Française pour l'avancement des Sciences, qui à l'époque du Congrès de Plymouth étaient réunis au Havre. Un mémoire y fut présenté de sa part, exprimant le désir de voir sa proposition acceptée, et demandant, dans l'intérêt commun de la Science, un bon accueil de l'Association Française, et son appui auprès du Ministre des Travaux Publics à Paris.

Grâce aux démarches qui furent faites plus tard par M. le Secrétaire du Conseil de l'Association Française, M. C. M. Gariel, auprès de M. A. Rousseau, Directeur du Département des Routes et de la Navigation au Ministère, son Excellence le Ministre des Travaux Publics a bien voulu donner l'autorisation nécessaire, en ce qui concernait les observations à faire sur les côtes de la France : et elles furent confiées par M. Rousseau à MM. les Ingénieurs des Ponts et Chaussées, attachés aux ports de Mer de la Manche.

Une semblable permission fut gracieusement accordée par son Excellence le Ministre des Travaux Publics de Belgique, grâce à l'intervention bienveillante de M. le Chevalier Maus, Inspecteur Général des Ponts et Chaussées, à Bruxelles, pour les observations du maréographe enregistreur (van Rysselberghe) à Ostende.

Le Gouvernement de sa Majesté Britannique accorda aussi la même permission, et se chargea de faire les observations nécessaires à certains endroits sur les côtes septentrionales de l'Angleterre. Plusieurs particuliers voulurent bien aussi se charger de faire des observations aux endroits indiqués, aussi bien en Hollande qu'en Angleterre.

Le programme suivant fut ensuite dressé pour régler une série d'observations simultanées en 1878, dans les mois de Février, Mars, Avril, Juin, et Août.

Pendant le premier trimestre, ce furent les marées d'équinoxe qu'on voulait étudier ; et dans les deux derniers mois les marées ordinaires. L'étendue des côtes du Continent comprises dans le programme s'étend depuis le Havre jusqu'à l'entrée du Canal de la Mer du Nord, qui conduit à Amsterdam ; et en Angleterre, depuis Portland, en face du Havre, jusqu'à Yarmouth, situé à peu près en face d'Amsterdam.

Dans le tableau comparatif qui suit, aussi bien que dans les courbes qui l'accompagnent, on n'a représenté que les marées d'équinoxe, qui ont été observées sur tous les points à la fois, dans le courant du mois de Mars. Il peut servir de type à celles des mois de Février et d'Avril, où les marées observées ont présenté une grande concordance avec celles qui sont dans le tableau.

Les observations des mois de Juin et d'Août de la même année, ainsi que d'autres résultats qu'on espère retirer de cette étude préliminaire sur les marées de la Manche et de la Mer du Nord, ne sont pas encore en état d'être présentées avec ce rapport.

La nécessité s'est bientôt fait sentir à la Commission de chercher un plan de comparaison commun, auquel toutes les observations pourraient être rapportées. Le seul moyen rationnel de comparer deux séries de nivellements opérés des deux côtes de la Manche paraissait de se servir

du niveau moyen de la mer ; et cette comparaison ne pouvait être qu'approximative. En supposant, en effet, que '*le niveau moyen de l'Océan Atlantique*,' donné par Bourdaloue dans son nivellement général de la France, représente le même plan que le '*mean sea level of the Ordnance Survey*' donne pour les côtes d'Angleterre, on trouve qu'un plan passant à 5·50 mètres en-dessous du zéro de Bourdaloue coïncide, à 0·01 mètre près, avec celui qui est à 20 pieds au-dessous de l''Ordnance Datum' de la Grande-Bretagne. En vue de l'approximation de laquelle on est forcé de se contenter, cette erreur peut être negligée. Ce plan de comparaison, outre l'avantage des chiffres ronds qu'il présente, a encore celui-ci qu'il n'y a que peu de basses mers d'équinoxe (même dans la Baie de St. Malo) qui descendent plus bas : et dans les observations qui sont à comparer aucun de ces cas exceptionnels ne se produit.

Dans le tableau comparatif des observations qui suit on a donc adopté ce plan de comparaison pour les nivellements des deux côtes de la Manche. Ceux de la Belgique et de la Hollande sont facilement rattachés au niveau de Bourdaloue au moyen des nivellements de précision faits dans chaque pays. C'est sur cette hypothèse de la coïncidence du niveau moyen de la mer qu'a été établie l'échelle comparative qui suit (voir Rapport, 1879, Pl. XIII.).

De l'examen attentif de ce tableau comparatif, on peut facilement conclure, que si sur une étendue considérable de côtes et pendant une durée de temps plus longue, il se faisait d'une manière regulière une série d'observations simultanées sur les marées, soit de quart d'heure en quart d'heure, ou même seulement aux moments de la haute et de la basse mer, on en retirerait probablement des résultats très-importants pour la science : tant au point de vue d'une connaissance plus exacte de ce qu'on appelle '*le niveau moyen*' de la mer, qu'à celui des moments exacts des hautes et des basses mers. On arriverait ainsi à se rendre meilleur compte des lois de la propagation de l'ondemarée dans les mers et détroits qui entourent nos côtes.

Mais une telle série d'observations ne peut être enterprise par une commission scientifique composée seulement de simples particuliers. Elle doit être la conséquence d'un accord entre les divers gouvernements des pays interéssés : chacun d'eux devrait se charger des observations à faire le long de ses propres côtes.

On a vu, qu'il a été nécessaire, dans la redaction des observations qui font l'objet de cette communication, d'essayer de résoudre le problème d'un plan de comparaison commun aux divers nivellements. L'importance de ce sujet a été déjà reconnu plusieurs fois par diverses commissions internationales. Si, à la suite des observations de marée ici rapportées, chaque gouvernement avait la complaisance de présenter à la commission sa manière de voir, soit sur le plan de comparaison choisi, soit sur tout autre qui lui paraîtrait préférable, ce serait un pas de gagné ; qui, lui seul, serait une récompense pour la commission en raison des travaux qu'elle a enterpris.

Il ne reste plus aux membres de la Commission de l'Association Britannique qu'à remercier, en leur nom personnel, les Gouvernements Français et Belge, par l'intermédiaire de leurs Excellences MM. le Ministres des Travaux Publics de chaque pays, aussi bien que le Gouvernement Anglais, pour l'appui bienveillant qu'ils ont donné chacun à ces observations des marées. Ils remercieront aussi l'Association Française pour l'avancement des Sciences, pour le bon accueil qu'elle a fait à la propo-

sition, et pour les encouragements qu'elle lui a donnés. Ils remercieront encore les observateurs particuliers (trop nombreux pour être nommés ici) qui ont si généreusement participé dans l'exécution du projet d'observations simultanées des marées de la Manche et de la Mer du Nord.

MARÉES DE LA MANCHE ET DE LA MER DU NORD.

Observations en 1878.

1. Observations chaque quart d'heure, de Basse Mer en Basse Mer.

Marée	Moment de la haute mer. (à Douvres).	
du 12 Février	5.46 soir.	Les observations doivent commencer une heure avant la première Basse Mer, et ne terminer qu'une heure après la dernière de chaque marée. Le moment *exact* des Hautes et des Basses Mers sera noté ; les autres observations à chaque quart d'heure exact (de l'horloge). Temps moyen de Paris sera observé partout.
19 „	0.31 „	
26 „	6.37 „	
13 Mars	5.23 „	
20 „	0.2 „	
27 „	6.16 „	
11 Avril	5.12 „	
18 „	11.35 matin	
25 „	5.39 soir.	

2. Observations sur les moments des Hautes et des Basses Mers seulement.

Au mois de Juin	Sur les marées du matin,	le 10	au 16	inclusives.
	„ „ soir,	„ 17	„ 24	„
Au mois d'Août	„ „ matin,	„ 8	„ 14	„
	„ „ soir,	„ 15	„ 23	„

N.B.—Il faudra à chaque endroit rattacher le zéro des observations avec le plan de comparaison des cartes du nivellement de la France. L'état du baromètre, et la direction et force du vent seront notés de temps en temps.

Endroits des Observations.

Yarmouth.
Lowestoft.
Harwich.
Sheerness.
Ramsgate.

Douvres.
Newhaven.
Shoreham.
Portland.

Mer du Nord, Entrée du Canal d'Amsterdam.
Flessingue.
Ostende.
Dunkerque.
Calais.

Boulogne.
Tréport.
Dieppe.
St. Valéry en Caux.
Fécamp.
Le Havre.

OBSERVATIONS SIMULTANÉES SUR LES MARÉES DE LA MANCHE ET DE LA MER DU NORD,
Le 13, 20, et 27 Mars, 1878.

Côte d'Angleterre

Endroits des Observations	Morte eau d'équinoxe			Vive eau d'équinoxe			Morte eau d'équinoxe		
	Heures	Hauteurs	Niveaux Rapportés	Heures	Hauteurs	Niveaux Rapportés	Heures	Hauteurs	Niveaux Rapportés
		Mètres			Mètres			Mètres	
Yarmouth	le 12, 7.10 soir.	0·53 B.M.	5·44	le 20, 2.16 matin.	−0·38 B.M.	4·53	le 26, 8.40 soir.	0·23 B.M.	5·14
	le 13, 2.41 matin.	1·80 P.M.	6·71	„ 10.4 „	1·75 P.M.	6·66	le 27, 3.35 matin.	1·30 P.M.	6·21
	„ 8.40 „	1·14 B.M.	6·05	„ 4.10 soir.	−0·25 B.M.	4·66	„ 10.10 „	0·76 B.M.	5·67
	„ 3.23 soir.	1·88 P.M.	6·79	„ 10.25 „	2·06 P.M.	6·97	„ 4.19 soir.	1·68 P.M.	6·59
	„ 9.10 „	0·43 B.M.	5·34	le 21, 4.50 matin	−0·31 B.M.	4·60	„ 10.20 „	0·36 B.M.	5·27
Lowestoft	„ 10.2 matin.	4·64 B.M.	6·62	le 20, 4.40 matin.	2·91 B.M.	4·89	„ 9.55 matin.	4·42 B.M.	6·40
	„ 3.47 soir.	5·40 P.M.	7·38	„ 10.47 „	5·29 P.M.	7·27	„ 4.10 soir.	5·22 P.M.	7·20
	„ 11.2 „	3·86 B.M.	5·85	„ 4.40 soir.	3·32 B.M.	5·31	„ 11.17 „	3·91 B.M.	5·90
Harwich	„ 11.47 matin.	2·24 B.M.	6·20	„ 6.40 matin.	0·38 B.M.	4·35	„ 11.40 matin.	2·11 B.M.	6·08
	„ 6.32 soir.	3·81 P.M.	7·78	„ 1.5 soir.	4·57 P.M.	8·54	„ 6.35 soir.	3·70 P.M.	7·66
	„ 11.32 „	1·49 B.M.	5·45	„ 6.55 „	0·71 B.M.	4·68	le 28, 1.32 matin.	1·59 B.M.	5·55
Sheerness	„ 12.40 „	−0·92 B.M.	5·62	„ 8.10 matin.	−3·25 B.M.	3·28	le 27, 12.25 soir.	−1·98 B.M.	4·55
	„ 7.10 „	1·35 P.M.	7·88	„ 1.45 soir.	2·54 P.M.	9·07	„ 7.40 „	1·25 P.M.	7·78
	—	—	—	„ 8.10 „	−2·95 B.M.	3·58	—	—	—
Ramsgate	„ 5.30 matin.	5·34 P.M.	7·86	„ 7.45 matin.	0·96 B.M.	3·49	„ 6.40 matin.	4·78 P.M.	7·30
	„ 12.5 soir.	3·10 B.M.	5·63	„ 12.50 soir.	6·18 P.M.	8·70	„ 12.32 soir.	2·97 B.M.	5·50
	„ 5.35 „	5 22 P.M.	7·75	„ 7.32 „	1·07 B.M.	3·59	„ 7.2 „	5·26 P.M.	7·79
Douvres	„ 12.30 „	1·83 B.M.	5·28	„ 7.10 matin.	−0·69 B.M.	2·76	„ 1.26 matin.	1·83 B.M.	5·28
	„ 5.30 „	4·32 P.M.	7·77	„ 12.10 soir.	5·85 P.M.	9·29	„ 5.42 „	3·94 P.M.	7·39
	—	—	—	„ 7.35 „	−0·69 B.M.	2·76	—	—	—
Newhaven	„ 5.25 „	4·40 P.M.	8·05	„ 12.20 „	6·46 P.M.	10·11	„ 6.10 soir.	4·70 P.M.	8·35
Shoreham	—	—	—	—	—	—	—	0·86 B.M.	4·59
	„ 4.44 „	3·51 P.M.	7·24	„ 11.59 matin.	5·57 P.M.	9·29	„ 5.34 soir.	3·97 P.M.	7·69
Portland	„ 7.35 matin.	0·65 B.M.	6·27	le 19, 11.17 soir.	−0·37 B.M.	5·25	„ 5.50 matin.	1·08 B.M.	6·70
	„ 11.47 „	1·09 P.M.	6·71	le 20, 3.55 matin.	2·08 P.M.	7·70	„ 8.48 „	1·37 P.M.	6·99
	„ 8.25 soir.	0·56 B.M.	6·18	„ 11.25 „	−0·36 B.M.	5·26	„ 6.55 soir.	0·60 B.M.	6·22

OBSERVATIONS SIMULTANÉES SUR LES MARÉES DE LA MANCHE ET DE LA MER DU NORD—*continued.*

CÔTE DE FRANCE

Endroits des Observations	Morte eau d'équinoxe			Vive eau d'équinoxe			Morte eau d'équinoxe		
	Heures	Hauteurs	Niveaux Rapportés	Heures	Hauteurs	Niveaux Rapportés	Heures	Hauteurs	Niveaux Rapportés
		Mètres			Mètres			Mètres	
Mer du Nord, Entrée du Canal d'Amsterdam	le 13, 2.50 matin.	1·11 B.M.	5·67	le 20, 0.50 matin.	1·18 B.M.	5·74	le 27, 5.5 matin.	0·93 B.M.	5·49
	„ 9.0 „	2·98 P.M.	7·54	„ 3.40 „	2·73 P.M.	7·29	„ 8.50 „	2·63 P.M.	7·19
	„ 4.0 soir.	1·23 B.M.	5·79	„ 12.0 midi.	0·53 B.M.	5·09	„ 5.20 soir.	1·28 B.M.	5·84
	„ 8.50 „	1·93 P.M.	6·49	„ 4.10 soir.	2·73 P.M.	7·29	„ 10.50 „	2·23 P.M.	6·79
	le 14, 4.50 matin.	0·91 B.M.	5·47	le 21, 0.50 matin.	0·85 B.M.	5·41	le 28, 6.30 matin.	1·07 B.M.	5·63
Flessingue	le 13, 6.40 „	1·59 P.M.	8·00	le 20, 8.35 „	−2·45 B.M.	3·96	le 27, 7.45 „	1·30 P.M.	7·71
	„ 1.10 soir.	−0·95 B.M.	5·46	„ 2.20 soir.	2·39 P.M.	8·80	„ 2.45 soir.	−0·75 B.M.	5·66
Ostende	le 12, 11.38 „	1·88 B.M.	4·37	le 19, 7.13 „	1·42 B.M.	3·91	„ 1.18 matin.	2·15 B.M.	4·64
	le 13, 6.19 matin.	4·70 P.M.	7·19	le 20, 0.35 matin.	6·28 P.M.	8·77	„ 7.10 „	4·89 P.M.	7·38
	„ 12.18 soir.	2·30 B.M.	4·79	„ 7.50 „	0·93 B.M.	3·42	„ 2.6 soir.	2·92 B.M.	5·41
	„ 7.5 „	4·42 P.M.	6·91	„ 1.13 soir.	6·18 P.M.	8·67	„ 7.50 „	4·82 P.M.	7·31
	le 14, 1.38 matin.	1·61 B.M.	4·10	„ 7.53 „	1·20 B.M.	3·69	le 28, 2.53 matin.	2·38 B.M.	4·87
Dunkerque	le 13, 1.15 soir.	2·00 B.M.	5·08	„ 7.30 matin.	0·00 B.M.	3·08	le 27, 1.15 soir.	2·05 B.M.	5·13
	„ 6.0 „	4·35 P.M.	7·43	„ 12.52 soir.	5·85 P.M.	8·93	„ 7.15 „	4·25 P.M.	7·33
	le 14, 1.0 matin.	1·44 B.M.	4·52	„ 7.22 „	0·15 B.M.	3·23	le 28, 2·22 matin.	1·60 B.M.	4·68
Calais	le 13, 12.2 soir.	−0·68 B.M.	4·82	„ 7.23 matin.	−3·20 B.M.	2·30	le 27, 1.5 soir.	−0·55 B.M.	4·95
	„ 5.56 „	1·95 P.M.	7·45	„ 12.33 soir.	3·96 P.M.	9·46	„ 7.6 „	2·10 P.M.	7·60
	le 14, 0.50 matin.	−1·10 B.M.	4·40	„ 7.43 „	−3·10 B.M.	2·40	le 28, 1.59 matin.	−0·85 B.M.	4·65
Boulogne	le 13, 12.0 midi.	12·70 B.M.	4·42	„ 7.45 matin.	10·04 B.M.	1·76	le 27, 12·45 soir.	12·92 B.M.	4·64
	„ 5.23 soir.	15·92 P.M.	7·64	„ 12.30 soir.	18·78 P.M.	10·50	„ 6.30 „	16·25 P.M.	7·97
	le 14, 0.31 matin.	12·52 B.M.	4·24	„ 8.0 „	9·99 B.M.	1·71	le 28, 1.45 matin.	12·78 B.M.	4·50
Tréport	le 13, 11.30 „	3·24 B.M.	4·53	„ 6.29 matin.	0·06 B.M.	1·35	le 27, 12.30 soir.	3·25 B.M.	4·54
	„ 5.15 soir.	6·60 P.M.	7·89	„ 12.3 soir.	10·18 P.M.	11·47	„ 6.10 „	6·95 P.M.	8·24
	le 14, 0.30 matin.	2·95 B.M.	4·24	„ 7.0 „	0·00 B.M.	1·29	le 28, 1.30 matin.	3·20 B.M.	4·49
Dieppe	le 13, 10.58 „	3·20 B.M.	4·49	„ 6.21 matin.	0·20 B.M.	1·49	le 27, 11.55 „	3·00 B.M.	4·29
	„ 4.55 soir.	6·25 P.M.	7·54	„ 11.55 „	9·78 P.M.	11·07	„ 6.10 soir.	6·87 P.M.	8·16
	„ 11.43 „	3·25 B.M.	4·54	„ 6.39 soir.	0·16 B.M.	1·45	le 28, 0.51 matin.	3·30 B.M.	4·59
Havre	„ 9.45 matin.	3·32 B.M.	4·43	„ 5.43 „	0·38 B.M.	1·49	le 27, 10.41 „	3·33 B.M.	4·44
	„ 3.30 soir.	5·84 P.M.	6·95	„ 9.58 „	8·15 P.M.	9·26	„ 5.26 soir.	6·33 P.M.	7·44
	„ 10.30 „	3·40 B.M.	4·51	le 21, 5.58 matin.	0·40 B.M.	1·51	„ 11.56 „	3·57 P.M.	4·68

NOTA.—Le temps indiqué est celui de Paris. Les niveaux sont rapportés à 5·50^{m} en-dessous du 'Zéro du Nivellement général de la France.' (ligne de Bourdaloue), en supposant que 'le niveau moyen de l'Océan Atlantique' est identique avec le niveau moyen ('Mean Sea Level') des côtes d'Angleterre.

List of Works on the Geology, Mineralogy, and Palæontology of Wales (to the end of 1873). *By* WILLIAM WHITAKER, *B.A., F.G.S., of the Geological Survey of England.*

[A communication ordered by the General Committee to be printed *in extenso* among the Reports.]

1. PREFATORY NOTICE.

THIS List, in which Monmouthshire is included with Wales, forms one of a set, the parts published or in the press being as follows:—

CAMBRIDGESHIRE. Pp. 15. Privately printed, University Press, Cambridge (1873). Reprinting, with additions, in the *Geological Survey Memoir* on the Neighbourhood of Cambridge.

CHESHIRE. *Proc. Liverpool Geol. Soc.* pp. 127–147 (1876).

CORNWALL. *Journ. R. Inst. Cornwall*, No. xvi. pp. 61–110 (1875).

DEVONSHIRE. *Trans. Devon. Assoc.* (1870), pp. 330–352, and vol. v. pp. 404–415 (1872).

FENLAND. By S. B. J. SKERTCHLY, pp. 306–313 of the *Geological Survey Memoir* on that district (1877).

GLOUCESTERSHIRE and SOMERSETSHIRE. By W. WHITAKER and H. B. WOODWARD, pp. 216–255 of the *Geological Survey Memoir* on the E. Somerset and the Bristol Coal-fields (1876).

HAMPSHIRE BASIN. *Journ. Winchester and Hants Sci. and Lit. Soc.* (1873), pp. 108–127.

HERTFORDSHIRE. *Trans. Watford Nat. Hist. Soc.* vol. i. pt. 3, pp. 78–82 (1876).

LAKE DISTRICT (N. part). By J. C. WARD [and W. WHITAKER], pp. 113–125 of the *Geological Survey Memoir* on the district (1876).

LANCASHIRE (part). Pp. 191–218 of the *Geological Survey Memoir* on the Burnley Coal-field (1875).

LONDON BASIN (part). Pp. 393–421 of *Geological Survey Memoirs*, vol. iv. (1872).

NOTTINGHAMSHIRE. Pp. 47–50 of the *Geological Survey Memoir* on sheet 71, N.E., ed. 2 (in the press).

RUTLAND (and parts of adjoining counties). Pp. 294–301 of the *Geological Survey Memoir* on the district, sheet 64 (1875).

WARWICKSHIRE. *Rep. Rugby School Nat. Hist. Soc.* for 1873, pp. 66–76 (1874).

WEALD. By W. TOPLEY, pp. 446–483 of the *Geological Survey Memoir* on the Weald (1875).

WILTSHIRE. *Mag. Wilts. Archæol. Nat. Hist. Soc.*, vol. xiv. pp. 107–121 (1873).

YORKSHIRE. Pp. 281–320 of Prof. J. PHILLIPS' *Illustrations of the Geology of Yorkshire*, part 1, 'The Yorkshire Coast,' ed. 3 (1875). Partly reprinted, with additions, in the *Geological Survey Memoir* on the Yorkshire Coalfield, pp. 786–806 (1878).

2. Index of Authors, with the Nos. prefixed to their Works.

3. Geological Survey Publications.

I have to thank my colleague, Mr. W. Topley, for aid in this part of the List, which includes a few works issued after 1873.

Sheets of the Map (scale, an inch to a mile).

(1) 35. N.W. part (Chepstow). By H. D. Williams, J. Phillips, and A. C. Ramsay. 1845. Additions, by H. W. Bristow, 1865.

(2) 36 (Merthyr, Bridgend, Cowbridge, Cardiff, Newport, Pontypool). By Sir H. T. De la Beche, Sir W. E. Logan, D. H. Williams, W. T. Aveline, and T. E. James. No date. Revisions, by H. W. Bristow and H. B. Woodward, 1873.

(3) 37 (Gower, Swansea, Neath, Llanelly). By Sir W. E. Logan and Sir H. T. De la Beche. No date. Revisions (S.E. margin), by H. B. Woodward, 1872.

(4) 38 (Milford, Pembroke, Tenby). By Sir H. T. De la Beche, A. C. Ramsay, J. Phillips, D. H. Williams, W. T. Aveline, and J. Rees. No date.

(5) 39 (Bishop and Clerks, islands). No date.

(6) 40 (St. David's, Haverfordwest, Narberth, Newport). By Sir H. T. De la Beche, J. Phillips, A. C. Ramsay, H. D. Williams, W. T. Aveline, and J. Rees. 1845. Additional lines, by W. T. Aveline, 1857.

(7) 41 (Caermarthen, Llandeilo, Llandovery, Newcastle-Emlyn). By Sir H. T. De la Beche, J. Phillips, and A. C. Ramsay. 1845. Additional lines, by W. T. Aveline, 1857.

(8) 42, S.W. (S.W. Brecknockshire). By Sir H. T. De la Beche, [Sir] W. E. Logan, and D. H. Williams. No date.

(9) 42, S.E. (Abergavenny, Crickhowel). By Sir H. T. De la Beche and D. H. Williams. No date.

(10) 42, N.W. (Brecknock). By Sir H. T. De la Beche, W. T. Aveline, J. Rees, and T. E. James, 1845. Additional lines, by W. T. Aveline. 1857.

(11) 42, N.E., greater part (Talgarth, Hay). By W. T. Aveline, T. E. James, and J. Rees. No date.

(12) 43, S.W., W. part (Monmouth). By D. H. Williams and T. E. James.

(13, 14) 56, S.W. (Builth) and N.W. (Rhayader). By A. C. Ramsay and W. T. Aveline. 1850.

(15) 56, S.E., greater part (New Radnor). By A. C. Ramsay, W. T. Aveline, H. W. Bristow, and T. E. James. 1850.

(16) 56, N.E., greater part (Knighton). By A. C. Ramsay, W. T. Aveline, and H. W. Bristow. 1850.

(17–19) 57, S.W. (Aberafron), N.W., and S.E. (Tregaron). By A. C. Ramsay. 1848.

(20) 57, N.E. (Aberystwyth). By A. C. Ramsay. The Lodes by Sir H. De la Beche and W. W. Smyth. 1848.

(21) 58 (Cardigan). No date.

(22) 59, S.E. (Coast S.W. of Machynlleth). By A. R. Selwyn. 1848.

(23) 59, N.E. (Coast N.W. of Machynlleth). By A. C. Ramsay and A. R. Selwyn. 1850. Corrections, 1855.

(24) 60, S.W. (Llanidloes). By A. C. Ramsay and W. T. Aveline. 1850.

(25) 60, S.E., W. part (Montgomery, Newtown). By A. C. Ramsay and H. W. Bristow. 1850.

(26) 60, N.W. (Dinas, Llanfair). By A. C. Ramsay, A. R. Selwyn, W. T. Aveline, and J. B. Jukes. 1851. Additions, 1855.

(27) 60, N.E., greater part (Welshpool). By A. C. Ramsay, W. T. Aveline, and E. Hull. 1850. Additions, 1855.

(28) 73, N.E., small part at N.W. By A. R. Selwyn. 1857.

(29) 74, S.W. (Bala). By A. C. Ramsay, J. B. Jukes, W. T. Aveline, and A. R. Selwyn. 1850. Corrections, 1855.

(30) 74, N.W. (Corwen). By A. C. Ramsay, J. B. Jukes, and W. T. Aveline. 1850. Corrections, 1855.

(31, 32) 74, S.E., W. half (Llanrhaiadr), and N.E., nearly all (Llangollen, Wrexham). By A. C. Ramsay, J. B. Jukes, W. T. Aveline, D. Williams, and E. Hull. 1850. Corrections, 1855.

(33) 75, S.W. (Pwllheli). By A. R. Selwyn. 1851.

(34) 75, S.E. (Harlech). By A. C. RAMSAY, A. R. SELWYN, and W. T. AVELINE. 1851. Corrections, 1855.

(35) 75, N.W. (Nevin). By A. C. RAMSAY and A. R. SELWYN. 1850.

(36) 75, N.E. (Tremadoc). By A. C. RAMSAY, A. R. SELWYN, W. T. AVELINE, and J. B. JUKES. 1851. Additions, 1854.

(37, 38) 76, S. and N. (E. end of Carnarvonshire). By A. R. SELWYN. 1850.

(39) 77, N. (Holyhead). By A. C. RAMSAY and A. R. SELWYN. 1852.

(40) 78, S.W. (Carnarvon, S. Anglesea). By A. C. RAMSAY, W. W. SMYTH, and A. R. SELWYN. 1852.

(41) 78, N.W. (N. Anglesea). By Sir H. DE LA BECHE, A. C. RAMSAY, W. W. SMYTH, and A. R. SELWYN. 1852.

(42, 43) 78, S.E. (Bangor, Beaumaris, Llanrwst), and N.E. (Conway). By A. C. RAMSAY, W. T. AVELINE, A. R. SELWYN, and J. B. JUKES. 1852.

(44) 79, S.W. (Denbigh, St. Asaph). By W. T. AVELINE. The Lodes by W. W. SMYTH. 1850.

(45) 79, S.E., nearly all (Flint, Mold). By W. W. SMYTH, D. H. WILLIAMS, W. T. AVELINE, and E. HULL. 1850.

(46) 79, N.W. (Abergele). By A. C. RAMSAY, W. T. AVELINE, and W. W. SMYTH. 1850.

(47) 79, N.E., S.W. corner (N. of Holywell). By W. W. SMYTH and E. HULL. 1850.

(48) 80, S.W., small piece at S.W. corner. By E. HULL. 1855.

Sheets of Index Map (scale, 4 miles to an inch).

(49) 9. (St. David's, Pembroke, Swansea, Llandovery.) 1858.

(50) 10. (Brecon, Monmouth, Newport, Cardiff, Chepstow.) 1858. New. ed. 1874.

(51) 14. (Aberystwyth, Cardigan.) 1858.

(52) 15. (Montgomery, Builth.) 1858.

(53) 19. (Anglesey, Carnarvon, Bangor.) 1858.

(54) 20. (Flint, Llangollen, Wrexham.) 1858.

Sheets of 'Horizontal Sections' (scale, 6 inches to a mile).

(55) 1. Section 1—From St. Bride's Bay, near Solva, to the North Cliff of Ynys-y-Barry. By A. C. RAMSAY and W. T. AVELINE. Section 2—Across Pembroke from St. Govan's Head to Dinas Head, near Fishguard. By Sir H. DE LA BECHE, A. C. RAMSAY, W. T. AVELINE, J. REES, and D. H. WILLIAMS. 1845.

(56) 2. Section 1—From the sea, near Tenby . . . . to Landewi Velfrey, Pembroke. Section 2—From near Cil-rhew . . . . to near Hendre, Pembroke. Section 3—Through Pant Yiar and Clog-y-Fran, Caermarthen. Section 4—From Laugharne to the river Dewi-Fawr, Caermarthen. Section 5—From Maes Gwrda to Mydrim, Caermarthen. Section 6—Across the Traps and Conglomerates of Pen-y-Moelfre, S.W. of Caermarthen. By Sir H. DE LA BECHE and J. PHILLIPS. 1844.

(57) 3. Section 1—Near Llandeilo, from Cerrig-dwfn to Mynydd-banc-y-ffair. Section 2—From near Llandibie to Llangathen. Section 3—From the Black Mountain, near Llangadoc, to Cefn-llwyn-hir, near Cynfil-Cays. By Sir H. DE LA BECHE, J. PHILLIPS, A. C. RAMSAY, and W. T. AVELINE. 1844.

(58) 4. Section from the Old Red Sandstone, Mynydd-Bwlch-y-groes,

Brecknock, to Craig-ddu, Cardigan Bay. . . . . By A. C. RAMSAY. 1845. Correction, by W. T. AVELINE, 1856. Notes on the Fossils by J. W. SALTER, 1857.

(59) 5. Section across the Old Red Sandstone and underlying Rocks, from the Black Mountain range S.E. of Glasbury, to Allt-wen, Cardigan Bay, near Aberystwyth. By A. C. RAMSAY and T. E. JAMES. 1845. Additions in 1858.

(60) 6. Section 1—Continuation of Sheet 5. Section 2—Across the Silurian Rocks, from Gwaun Ceste to Rhiw Gwraidd, Radnor. By A. C. RAMSAY (? and T. E. JAMES). No date (? 1845).

(61) 7. Section 1—Across the Coalfield of South Wales, from the Mountain Limestone near Mynydd Garreg to the Mountain Limestone near Spiritsail Tor, Gower. Section 2—On the North Crop of the South Welsh Coalfield, from Brondyne Hill to the Mountain Limestone near Yr Hen Coed, Caermarthen. Section 3—From Penclawdd, ... to Oxwich Point, Gower. By [Sir] W. E. LOGAN. No date.

(62) 8. Section across the Coal Measures of Caermarthenshire and Glamorganshire from the Carboniferous Limestone on the north of Cottage Hall, to the Sea, in Caswell Bay. By [Sir] W. E. LOGAN and W. P. STRUVE. No date.

(63) 9. Section 1—Across the South Wales Coalfield, from Craig and Cefn Drim to the Mountain Limestone at Caswell Bay, Gower, Glamorgan. Section 2—From Cilfay Hill, Swansea, to Castell Craig Cennen . . . . By [Sir] W. E. LOGAN. No date.

(64) 10. Section 1—Across part of the Coalfield of Glamorgan, from near Bryn Cethin Uchaf to Blaen Afon. Section 2—Across part of the Coalfield of Glamorgan, from Mynydd Moel Genlam to Mynydd Llandyfodwg. Section 3—Across part of the Coal Field of Glamorgan, from the Ogmore near Bryn Menyn to Blaen Afon. Section 4—Coal Measures of Glamorgan, from Trecastell to the Rhondda. By Sir H. DE LA BECHE and D. H. WILLIAMS. No date.

(65) 11. Section near the Bendrick Rock, near Barry Island, Glamorgan, to Allt Llwyd, Brecknock. By Sir H. T. DE LA BECHE and D. H. WILLIAMS. 1848.

(66) 12. Section from the Ebwy River, near Cefn Crib, Monmouth, across the Forest of Dean . . . . By T. E. JAMES, H. W. BRISTOW, and D. H. WILLIAMS. No date.

(67, 68) 26 and 27. From Cardigan Bay over Cader Idris . . . . to Fern Hall, S. of Kington Hereford. By A. C. RAMSAY, A. R. SELWYN, W. T. AVELINE, and H. W. BRISTOW. 1852.

(69–71) 28, 29, and 30. Section from Llanfair-is-gaer, Menai Straits, over Snowden . . . . to the Old Red Sandstone near Ludlow. By A. C. RAMSAY, A. R. SELWYN, W. T. AVELINE, and H. W. BRISTOW. 1853.

(72–74) 31, 32, and 33 (part). Section from the Suspension Bridge Menai Straits [to the river Camlad, 6 miles S.E. of Welshpool]. By A. C. RAMSAY, A. R. SELWYN, W. T. AVELINE, and J. B. JUKES. 1854.

(75) 34. Section from the Vale of Severn, near Welshpool, Montgomeryshire, to Corne Dale, Shropshire. . . . . By W. T. AVELINE. 1854.

(76) 35. From Cwm Cywen, 4½ miles N.E. of Bala, over Cader Berwyn, the Breidden Hills. . . . . By J. B. JUKES and W. T. AVELINE. 1853.

(77) 37. Section from Harlech, Cardigan Bay, ... over the Ber-

wyns to the Carboniferous Limestone near Oswestry. By A. C. RAMSAY, W. T. AVELINE, and A. R. SELWYN. 1854.

(78) 38. Section 1—Continuation of section on Sheet 37. Section 2 —From $3\frac{1}{2}$ miles W.N.W. of Meifod, Montgomery, to the head of the Vale of Clwyd. By J. B. JUKES and W. T. AVELINE. 1855.

(79) 39. Section from Arenig-fawr to the Coal Measures, near Wrexham. By J. B. JUKES and W. T. AVELINE. 1855.

(80) 40. Section from Porth Llanlliana . . . . across Anglesea to the Menai Straits. Section across Anglesea from Point Ælianus to the Menai Bridge. By A. C. RAMSAY and H. BAUERMAN. 1857.

(81) 43. Across the Wenlock Shale W. of Ruthin, the . . . . Vale of Clwyd; the Flintshire Coal Field between Mold and the Dee. By W. T. AVELINE, E. HULL, and H. BAUERMAN. 1858.

(82) 44. No. 1—Across the Denbighshire Coalfield, through Bwlch Gwyn and Brymbo; the Permian Rocks North of Wrexham. . . . . By D. H. WILLIAMS and E. HULL. No. 2—Through Tan-y-Castell across the Denbighshire Coal-field. . . . . By D. H. WILLIAMS. 1858.

(83) 107. Section from Portskewet in Monmouthshire, across the River Severn at New Passage. . . . . By J. ANSTIE and H. B. WOODWARD. 1875.

Sheets of 'Vertical Sections' (scale, 40 feet to an inch).

(84) 1. Section at Moreb, Pembray, Trim Saran, Cil Rhedyn, and Mynydd Garreg to the bottom of the Mountain Limestone, Cwn Caer Cefn. By [Sir] W. E. LOGAN. No date.

(85) 2. The Coal Measures at Llwchwr and Penclawdd, Glamorgan. By [Sir] W. E. LOGAN. No date.

(86) 3. From Werndu Seam of Coal to the Two-feet Seam, Cwm Afon Section at Brondine, Pont-yates, Maensant, and Yr Hencoed. By [Sir] W. E. LOGAN. No date.

(87) 4. Section of the Coal Measures near Llandebie, Caermarthen; Cwm Twrch, Brecknock; Cwm Gwendraeth; Lansamlet, near Swansea; Bryn Coch Dyffryn, Neath. By [Sir] W. E. LOGAN. No date.

(88) 5. The South Welsh Coal Measures from Penllergare, Glamorgan, to near Tair Carn, and Pant-y-gwaslad, Caermarthen. By Sir H. DE LA BECHE. No date.

(89) 6. The Coal Measures from Penllergare to Bishopston, near Swansea. By Sir H. DE LA BECHE. No date.

(90) 7. The Coal Measures at Llangeinor, Glamorgan. By Sir H. DE LA BECHE and [Sir] W. E. LOGAN. No date.

(91) 8. The Coal Measures in South Wales and Monmouth. By D. H. WILLIAMS. No date.

(92) 9. The Lower or Ironstone Coal Measures in Glamorgan and Monmouth, illustrative of their decrease from Aberdare eastward to Abersychan. By D. H. WILLIAMS. No date.

(93) 10. Diagram illustrating the variation of the principal Coal Seams in their range from Merthyr Tydvil to Pont-y-pool (scale 3 feet to an inch). By D. H. WILLIAMS. No date.

(94) 12. Illustrative of the passage of the Old Red Sandstone into the Carboniferous Limestone in South Wales. By Sir H. DE LA BECHE, A. C. RAMSAY, W. T. AVELINE, and J. REES. No date.

(95) 13. Section of the Old Red Sandstone and Silurian Rocks (of South Wales). By Sir H. DE LA BECHE and Prof. J. PHILLIPS. No date.

(96) 14. Through the Tilestone and Upper and Lower Silurian Strata; at Golden Grove near Llandeilo and in the bed of the Sawdde River, near Llangadoc. By Sir H. De la Beche and Prof. J. Phillips. No date.

(97) 24. Section of the Coal Measures between Sweeney Mountain near Oswestry and Brymbo N.W. of Wrexham. By D. H. Williams. No date.

(98) 47. Section of the Lower Lias and Rhætic or Penarth Beds of Glamorgan. By H. W. Bristow and R. Etheridge, 1873.

(99) 53. Section of the Coal-Measures . . . . from Glyncorrwg Fault to Pembrey Bar Fault; on the South Crop, north of Anticlinal. By H. H. Vivian and E. Daniel, 1873.

(100) 57. Section of the Coal Measures . . . . from Glyncorrwg Fault to Pembury Bar Fault; South of Anticlinal. By H. H. Vivian and E. Daniel, 1874.

(101) 58. Section of the Coal Measures . . . . from Glyncorrwg Fault to Pembury Bar Fault on the North Crop. By H. H. Vivian and E. Daniel, 1874.

(102) 59. Section of the Coal Measures . . . . from Glyncorrwg Fault to Pembury Bar Fault on the North Crop. By H. H. Vivian and E. Daniel, 1876.

Memoirs (8vo. London).

(103) Vol. i. (1846). Sir H. De la Beche. 'On the Formation of the Rocks of South Wales and South-western England,' pp. 1–296.—Prof. A. C. Ramsay. 'On the Denudation of South Wales and the adjacent Counties . . . . pp. 297–335.—W. W. Smyth. 'Note on the Gogofau or Ogofau Mine,' pp. 480–484.

(104) Vol. ii. part 2 (1848). Dr. W. Hooker. 'Remarks on the Structure and Affinities of some Lepidostrobi,' p. 440 (Wales, pl. 7).—Prof. E. Forbes. 'On the Asteriadæ found fossil in British Strata' (Wales, p. 463), and 'On the Cystideæ of the Silurian Rocks of the British Islands' (Wales, pp. 512–516, 518, 521–523).—Sir H. De La Beche and Dr. L. Playfair. 'First Report on the Coals suited to the Steam Navy' (Wales, pp. 550, 571–588, 593–600, 610, 621, &c.).—R. Hunt. 'Notices of the History of the Lead Mines of Cardiganshire,' pp. 635–654.—W. W. Smyth. 'On the Mining Districts of Cardiganshire and Montgomeryshire,' pp. 655–684.

(104*a*) Vol. ii. part 1 (1848). J. Phillips. The Malvern Hills, compared with the Palæozoic Districts of Abberly, Woolhope, May Hill, Tortworth and Usk [refers to South Wales], pp. 1–330. Palæontological Appendix, by J. Phillips and J. W. Salter, pp. 331–386.

(105) Vol. iii. (1866). 'The Geology of North Wales.' By Prof. A. C. Ramsay. With an Appendix on the Fossils. By J. W. Salter.

(106) The Iron Ores of Great Britain. Part 3. South Wales. Pp. 106–236 (1861). Notes on the Fossils. By J. W. Salter (pp. 219–236).

(106*a*) Figures and Descriptions illustrative of British Organic Remains. Decade I. Asteriadæ and Echinidæ, by Prof. E. Forbes, 1849. Decade II. Trilobites, by Prof. E. Forbes and J. W. Salter, 1849. Decade VII. Trilobites, by J. W. Salter, 1853. Decade XI. Trilobites, by J. W. Salter, 1864.

(106*b*) Catalogue of the Contents of the Mining Record Office . . . .

consisting of Plans and Sections of Mines and Collieries . . . . By R. HUNT and R. MEADE, 1858.

(106c) A Descriptive Catalogue of the Rock Specimens in the Museum of Practical Geology, with Explanatory Notices of their Nature and Mode of Occurrence in Place, 1858. By A. C. RAMSAY, &c. Ed. 2, 1859; Ed. 3, 1862.

(106d) A Catalogue of the Mineral Collections in the Museum of Practical Geology, with Introductory and Explanatory Remarks. By W. W. SMYTH, T. REEKS, and F. W. RUDLER, 1864.

(106e) A Catalogue of the Collection of Fossils in the Museum of Practical Geology, with an Explanatory Introduction, 1865. By T. H. HUXLEY and R. ETHERIDGE. [Practically a new ed. in parts.—"A Catalogue of the Cambrian and Silurian Fossils in the Museum of Practical Geology," and "A Catalogue of the Tertiary and Post Tertiary Fossils in the Museum of Practical Geology" (Moel-y-Tryfan Shells, p. 81). By T. H. HUXLEY, R. ETHERIDGE, and E. T. NEWTOON, 1878.]

4. BOOKS, PAPERS, &C., CHRONOLOGICALLY ARRANGED.

This list does not extend beyond 1873, after which date the yearly *Geological Record* notices all works on Geology.

1677.

(107) MOSTYN, R. A Relation of some strange phænomena, accompanied with mischievous effects in a Cole-work in Flint-shire. *Phil. Trans.* vol. xii. (No. 136), p. 895.

1684.

(108) LLOYD, E. An Account of a Sort of Paper made of Linum Asbestinum found in Wales. *Phil. Trans.* vol. xiv. (No. 166), p. 823.

1697.

(109) AUBRY, —. Part of a Letter concerning a Medicated Spring in Glamorganshire. *Phil. Trans.* vol. xix. (No. 233), p. 727.

1698.

(110) ANON.? (? Title.) [Old Lead and Silver Mines. A description of the Lead and Silver Mines worked in 1698, in the vicinity of Eskir Hir . . . .] Map and plans.

(111) LLHWYD, E. Part of a Letter concerning several regularly Figured Stones, lately found by him. *Phil. Trans.* vol. xx. (No. 243), p. 279.

1699.

(112) LLWYD, [E.] Part of a Letter concerning a Figured Stone found in Wales, with a Note on it by Dr. H. SLOANE. *Phil. Trans.* vol. xxi. (No. 252), p. 187.

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(113) ANON.? (Old Lead and Silver Mines at Bwlchyr Esker-Hyr. A Familiar Discourse or Dialogue concerning the Mine Adventure [in Cardiganshire] . . . . 8vo. *Privately printed* (pp. 170).

(114) WALLER, W. State of the Lead, Silver, and other Mines in Wales. (? date). 8vo.

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(115) LLHWYD, E. A Letter containing several Observations in Natural History, made in his Travels thro' Wales. *Phil. Trans.* vol. xxvii. (No. 334), p. 462.

(116) —— Some farther Observations relating to the Natural History of Wales. *Ibid.* p. 467.

(117) —— A Letter giving a farther Account of what he met with remarkable in Natural History and Antiquities in his Travels thro' Wales. *Ibid.* (No. 335), p. 500.

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(118) LHWYD, E. Extracts of several Letters containing Observations in Natural History and Antiquities, made in his Travels thro' Wales, &c. *Phil. Trans.* vol. xxviii. p. 93.

(119) —— An Extract of a Letter containing some remarks on an Undescribed Plant, and other Particulars, observed in Wales. *Ibid.* p. 275.

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(120) ROWLANDS, H. Mona Antiqua Restaurata. An Archæological Discourse on the Antiquities, Natural and Historical, of the Isle of Anglesey. 4to. *Dublin.* Another ed. 4to. *Lond.*, in 1766.

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(121) LINDEN, Dr. D. W. A Treatise on the Three Medicinal Mineral Waters at Llandrindod, in Radnorshire, South Wales, with some Remarks on Mineral and Fossil Mixtures, in their Native Veins and Beds; At least as far as respects Their Influence on Water. 8vo. *Lond.*

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(122) MATTHEWS, E. An Account of the Sinking of a River near Pontypool in Monmouthshire. *Phil. Trans.* vol. xlix (part 2), p. 547.

(123) PENNANT, T. An Account of some Fungitæ and other curious coralloid fossil Bodies. *Ibid.* p. 513.

1758.

(124) DA COSTA, E. M. An Account of the Impressions of Plants on the Slates of Coals. *Phil. Trans.* vol. l. p. 228.

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(125) RUTTY, Dr. J. Of the vitriolic Waters of Amlwch, in the Isle of Anglesey; with occasional Remarks on the Hartfell Spaw . . . . and their Comparison with other Waters of the same Class. *Phil. Trans.* vol. li. p. 470.

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(126) MORRIS, Dr. M. A short Account of some Specimens of native Lead found in a Mine of Monmouthshire. *Phil. Trans.* vol. lxiii. (part 1), p. 20.

1778–83.

(127) PENNANT, T. A Tour in Wales. (Mineral Tract, &c. pp. 415–424.) 4to. *Lond.*

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(128) Williams, J. The Natural History of the Mineral Kingdom. 2 vols. 8vo. *Edin.* (Wales, vol. i. pp. 274, &c., 357, 410.) A 2nd edition.

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(129) Beddoes, Dr. T. Observations on the Affinity between Basaltes and Granite. *Phil. Trans.* vol. lxxxi. p. 48.

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(130) Owen, G. [? Title.] *Cambrian Register* (written in 1570).

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(131) Aikin, A. Journal of a Tour through North Wales and part of Shropshire, with Observations in Mineralogy and other branches of Natural History. 8vo. *Lond.* [See also *Journ. Nat. Phil. Chem. Arts*, vol. i. pp. 220, 367 (1797), 4to.]

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(132) Kirwan, R. Experiments on the Composition and Proportion of Carbon in Bitumens and Mineral Coal. *Journ. Nat. Phil. Chem. Arts*, (4to.) vol. i. p. 487.

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(133) Lentin, A. G. L. Briefe über die Insel Anglesea, vozuglich über die dasigen Kupferbergwerke und die dazu gehörigen Schmelzwerke und Fabriken. 8vo. *Leipzic.*

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(134) Williams, W. Observations on the Snowdon Mountains, &c. 8vo.

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(135) Klaproth, M. H. Extracts from the third vol. of his Analyses (Lead Ore of Anglesea). *Phil. Mag.* vol. xvii. p. 230.

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(136) Hatchett, C. An Analysis of the magnetical Pyrites; with Remarks on some of the other Sulphurets of Iron. *Phil. Trans.* vol. xciv. p. 315. Reprinted in *Phil. Mag.* vol. xxi. pp. 133, 213 (1805), and in *Journ. Nat. Phil. Chem. Arts*, ser. 2, vol. x. p. 265, and vol. xi. p. 6 (1805).

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(137) Martin, E. Description of the Mineral Bason in the Counties of Monmouth, Glamorgan, Brecon, Carmarthen, and Pembroke. *Phil. Trans.* vol. xcvi. p. 342. Reprinted in *Journ. Nat. Phil. Chem. Arts*, ser. 2, vol. xvi. p. 381 (1807); and vol. xix. p. 361 (1808).

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(138) Donovan, — Account of an extinct Volcano in Britain (Cader Idris). *Journ. Nat. Phil. Chem. Arts*, ser. 2, vol. xix. p. 237.

(139) Mushet, D. Analysis of various Kinds of Pit-coal. *Phil. Mag.* vol. xxxii. p. 140. (Wales, pp. 140, 142.)

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(140) BOYD, C. Chemical Analyses of Soils, &c. No. 18, Limestone from Monmouthshire. *Letters and Papers Bath W. Engl. Soc.* vol. xii. p. 379.

(141) HOWELL, — Analysis of the Carbonated Chalybeate Well lately discovered at Middleton Hall, near Llanarthney, in Carmarthenshire. The Analytical Results by Mr. ACCUM. *Phil. Mag.* vol. xxxv. p. 179.

(142) MEYRICK, S. R. History and Antiquities of the County of Cardigan, with its Mineralogical and Agricultural State. (Mineralogy, p. cciii.) 4to. *Lond.*

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(143) EVANS, Rev. J. The Beauties of England and Wales, vol. xvii. part 1, North Wales. (Minerals, &c. pp. 82–94.) 8vo. *Lond.*

(144) HASSALL, C. General View of the Agriculture of the County of Monmouth. (Account of Soils and Minerals.) 8vo. *Lond.*

(145) MUSHET, D. On certain Points connected with the Super-position of the Strata of England. *Phil. Mag.* vol. xl. p. 49.

(146) SOWERBY, J. The Mineral Conchology of Great Britain, vol. i. (p. 30). 8vo. *Lond.*

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(147) DAVIES, W. General View of the Agriculture and Domestic Economy of North Wales. (Account of Soils and Minerals, pp. 33–72.) 8vo. *Lond.*

(148) FAREY, J. Cursory Geological Observations lately made, in Shropshire, Wales, &c. . . . . *Phil. Mag.* vol. xlii. p. 53.

(149) —— Notes and Observations on . . . . Mr. R. Bakewell's 'Introduction to Geology.' . . . . *Ibid.* vol. xliii. p. 356. (Wales, pp. 359–61.)

(150) TOWNSHEND, Rev. J. The Character of Moses established for veracity as an Historian, recording events from the Creation to the Deluge. 4to. *Bath* and *Lond.*

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(151) ANON. Stratification of Glamorganshire. *Phil. Mag.* vol. xliv. p. 427.

(152) BINGLEY, Rev. W. Excursion through all the most interesting Parts of . . . . North Wales, ... with account of the Copper Mines . . . . in Anglesea. 8vo.

(153) KIDD, Dr. J. Notes on the Mineralogy of the neighbourhood of St. David's, Pembrokeshire. *Trans. Geol. Soc.* vol. ii. p. 79.

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(154) FAREY, J. Short Notices of Geological Observations made in . . . . the South of Yorkshire and in North Wales, and of some Inferences therefrom, as to the Structure of England and Wales. *Phil. Mag.* vol. xlv. p. 161.

(155) KIDD, Dr. J. A Geological Essay on the Imperfect Evidence in support of a Theory of the Earth, &c. 8vo. *Oxford.* (Wales, pp. 99, 100–103, 110, 119, 120.)

(156) PRICHARD, Dr. J. C. Geological Observations on North Wales. *Ann. Phil.* vol. vi. p. 363.

(157) REES, T. The Beauties of England and Wales, vol. xviii. South Wales. (Notices of Minerals, &c.) 8vo. *Lond.*

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(161) Gilby, Dr. W. H. Some Observations respecting the Geology of South Wales. *Ann. Phil.* vol. ix. p. 114.

(162) Smith, W. Geological Section from London to Snowdon, showing the Varieties of the Strata, and the correct Altitude of the Hills. *Lond.*

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(163) Paris [Dr.], J. A. A New Substance, found accompanying 'Welsh Culm.' *Trans. Roy. Geol. Soc. Cornwall*, vol. i. p. 229.

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(164) Aikin, A. Observations on the Vallies and Watercourses of Shropshire and of part of the adjacent Counties. *Trans. Geol. Soc.* vol. v. p. 73.

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(166) Fosbroke, J. Geological Description of the Hills which pursue the Course of the Wye, from Ross to Chepstow, with Remarks upon the Characteristics of the Herefordshire Formations, and an Outline of the Stratifications of the Forest of Dean, and the opposite Shores of the Severn. *Quart. Journ. Sci. Lit. Arts*, vol. ix. p. 35.

(167) Gilby, Dr. [W. H.] Account of the Trap and Clay-slate Formation extending from Llandegly to Builth in Brecknockshire. *Edin. Phil. Journ.* vol. ii. p. 253.

(168) Sowerby, J. The Mineral Conchology of Great Britain, vol. iii. (p. 123). 8vo. *Lond.*

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(169) Conybeare, Rev. J. J. Description of a new Substance (Hatchetine) found in Ironstone. *Ann. Phil.* ser. 2, vol. i. p. 136, and vol. v. p. 190 (1823).

(170) Traill, Dr. T. S. Observations on the Mineralogy of Halkin Mountain, in Flintshire; with a particular account of the recently discovered Buhrstone and Porcelain-Clay of that place. *Edin. Phil. Journ.* vol. iv. p. 246.

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(172) Buckland, Rev. Prof. W. Account of an assemblage of Fossil Teeth and Bones, of Elephant, Rhinoceros, Bear, Tiger, and Hyæna, and

sixteen other Animals; discovered in a Cave at Kirkdale, Yorkshire . . . . with a Comparative View of five similar Caverns in various Parts of England, &c. *Phil. Trans.* vol. cxii. p. 171. Reprinted in *Ann. Phil.* ser. 2, vol. iv. pp. 133, 173.

(173) HENSLOW [Prof.], J. S. Geological Description of Anglesea. *Trans. Cambridge Phil. Soc.* vol. i. p. 359.

(174) PHILLIPS, W. and S. WOODS. Sketch of the Geology of Snowdon and the surrounding Country. *Ann. Phil.* ser. 2, vol. iv. pp. 321, 401.

(175) SOWERBY, J. The Mineral Conchology of Great Britain, vol. iv. (pp. 31, 32). 8vo. *Lond.*

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(176) BUCKLAND, Rev. Prof. W. Reliquæ Diluvianæ; or Observations on the Organic Remains contained in Caves, Fissures, and Diluvial Gravel, and on other Geological Phenomena, attesting the action of an Universal Deluge. 4to. *Lond.* (Wales, pp. 80, 166, 177, 206.)

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(179) ANON. (C. C. C.) On the Geology of Snowdon. *Ann. Phil.* ser. 2, vol. ix. p. 74.

(180) DUFRÉNOY, P. A. Gisement des minerais de Zinc en Angleterre. *Ann. Mines*, t. x. p. 481.

(181) —— and E. DE BEAUMONT. Sur le Gisement, l'exploitation et le traitement des minerais d'étain et de cuivre du Cornouailles. *Ibid.* p. 401. (Anglesey, p. 403.)

(182) LÉVY, — An Account of a new Mineral (Brookite, from Snowdon). *Ann. Phil.* ser. 2, vol. ix. p. 140.

(183) THOMSON, E. P. On the discovery of Selenium in the Sulphuric Acid made from the Pyrites of Anglesey. *Ibid.* p. 52.

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(187) DUFRÉNOY, P. A., and E. DE BEAUMONT. Voyage Métallurgique en Angleterre. 8vo. *Paris.* (S. Wales, p. 399.) Ed. 2, vol. i. in 1837, vol. ii. in 1839.

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On the recent Revival in Trade. By STEPHEN BOURNE, *F.S.S.*

[A communication ordered by the General Committee to be printed *in extenso.*]

THE latest issued official accounts of the foreign and colonial trade of the United Kingdom, together with those of the several preceding months, bear testimony to a very considerable increase in the quantity and value of both imports and exports. The figures in which these are set forth have been received as evidence that a real revival of trade has set in, and is about to extend beyond the bounds which have been reached in former years. Such an analysis of these figures as may serve to indicate their real bearing on the welfare of the country—both present and future—will not, therefore, be uninteresting, either to those engaged in trade or manufacture; nor to those who are any way concerned to understand the position in which we stand, or that to which we may look forward.

It was during the sitting of the British Association in the manufacturing town of Sheffield last year, that the first gleams of returning prosperity were distinctly seen. There had been for some months previously more frequent appearances of 'paper' in the London Money Market, of American origin, which were taken as indications that there was a stir in American trade; and many proofs that the depression into which trade on the other side of the Atlantic had fallen was passing away. Not a few hopes were expressed that this country would in like manner emerge from the depth into which its trade had fallen, so soon as prosperity was again brightening the prospects of the United States. The receipt, therefore, of orders for various descriptions of our iron products—and especially for rails—was immediately viewed as a precursor to manufacturing activity. Nor was the expectation unwarranted by the results. A spirit of confidence at once sprung up, and prices rose so high as to show that in addition to that which had a sound basis, much speculative business was going on. Thus a stimulus was given to production. Higher prices were asked and given, and for a time there seemed to be no lack of buoyancy in almost every market. Prices again gave way, but are now being partially recovered, and the opinion is almost universally entertained that a new era of prosperity is being entered upon. Such being the case it may be worth while to compare a year's transactions with those of the preceding one. The early date at which the monthly accounts are now issued from the Custom House gives us the means of taking for such comparison the twelvemonth

ended July 31 last with those which came to a conclusion on the last day of July in 1879. We can thus place side by side the figures for the worst year of depression and the first year of recovery.

Before entering into an examination of the details of the last two years, it may be well to state the totals for each year since 1871—that is, so far back as they were collected on the same system as now exists; and to show the difference in value between the goods imported and those exported, as follows:—

[In millions of £'s to two decimals.]

Year ending	Imports	Exports	Excess of Imports
	£	£	£
July 31, 1880	404·31	271·24	133·07
" 1879	345·78	239·86	105·92
" 1878	387·35	250·59	136·76
" 1877	389·76	254·31	135·45
" 1876	372·37	266·81	105·56
" 1875	369·48	288·87	80·61
" 1874	375·12	301·23	73·89
" 1873	366·43	320·72	45·71
" 1872	349·85	304·73	45·12

It will thus be seen that of the imports the twelve months just ended were the highest, and those of the preceding twelve the lowest of the whole series. Of the exports, the period ending in 1879 was likewise the lowest, but that just ended was by no means the highest; whilst as regards the preponderance of imports, the most recent is very nearly the greatest, there having been, until 1880, a progressive decline in the value of the exports. Comparing the years ending in 1880 and 1879 together, they differ in all these particulars more widely from each other than any of the preceding years, the growth in imports having been 58·53*l.*, in exports 31·38*l.*, and in the excess of the former 27·15*l.* These figures include the whole of the imports—those again sent away, as well as those retained for home consumption; and of the exports both the re-exports and the articles of British produce and manufacture.

Separating one class of exports from the other, it appears that in the latter year they have amounted in value to 214,000,000*l.* British, and about 57,000,000*l.* foreign and colonial, as against 187,000,000*l.* of the one and 53,000,000*l.* of the other. These figures are not exact, for the accounts of the foreign goods are only shown in total at the proper end of each year, but they are accurate enough for the present purpose, and tell the increase of British to have been twenty-seven, and in foreign between four and five millions of pounds. These foreign and colonial goods show the activity of trade, and add to the national receipts by the commissions and profits on their sale, but, as regards the employment of labour and capital, are of inferior importance to the British.

In estimating the worth of this increase, very much depends upon whether it has taken place in the quantities of the goods that have been sold, or in the prices they have realised. From so many of the articles being shown in the accounts in value only it is not possible to say how this may have been as regards the whole, but by abstracting the principal articles that are stated, both quantity and value, the relation of the one to

the other may be ascertained for such portion of the exports, and it is not likely that the proportions of the remainder will vary greatly. Classifying the articles so abstracted, and calculating how far the difference in value is due to greater quantities or altered values, the following results appear. As before, in million pounds to two decimals:—

	Value of Exports 1879–80	More or less than 1878–79	Increase or Decrease due to	
			Quantity	Price
	£	£	£	£
Coals	8·01	·96	1·13	−·17
Copper	3·16	·24	·10	·14
Iron	26·12	8·44	7·63	·81
Mineral	37·29	9·64	8·86	·78
Cotton Piece Goods	53·42	7·30	7·59	−·29
Jute " "	2·12	·30	·26	·04
Linen " "	5·03	·49	·44	·05
Woollen " "	15·95	1·19	1·83	−·64
Textile	76·52	9·28	10·12	−·84
Cotton and other yarns	19·02	·01	−·58	·59
Alkali	2·32	·38	·24	·14
Beer	1·73	−·09	−·09	—
Leather	2·92	−·09	−·23	·14
Seed-oil	1·61	·01	−·03	·04
Sundry	27·60	·22	−·69	·91
Total specified	141·41	19·14	18·29	·85

Since the full value of all the British manufactures exported for the year is 214 millions, and that of these specified articles is nearly 142, the evidence thus afforded relates to two-thirds of the whole. In like manner with the increase, twenty-seven millions for the whole and nineteen for the enumerated.

Examining these particulars more closely, it will be seen that the increase of 19·14*l.* is between 15 and 16 per cent. on the exports of the previous twelve months, and that of this amount 18·29*l.*, or 95½ per cent., is owing to the quantities having been greater, and only ·85*l.*, or 4½ per cent., has arisen from better prices having been obtained. But whilst these are the proportions of the whole, the rates on the different classes of goods differ very much. Thus in coals and metals the increase has been 35 per cent., on textile manufactures 14 per cent., and in the miscellaneous less than 1 per cent. So in respect to the gain in quantities, the minerals are greater by 92 per cent., and the prices are better by 8 per cent. In textile fabrics the increased quantities should have given 9 per cent. more money than was actually credited, but failed to do so because the prices were less to this extent. On the contrary, in the few miscellaneous articles shown above there was a real diminution of quantity, but an increase in price, whereby what would have been a loss of 2½ per cent. became converted into a gain of something less than 1 per cent. Descending more into detail,

iron figures for very nearly one-third of the whole year's gain, viz., 8·44*l.* out of 27*l.*, and cotton piece goods for 7·30*l.*, or one-fourth. Of the gain in iron, one-tenth only is due to price, whilst cotton goods have sold for a trifle less than the previous price. On the other hand, cotton yarn has decreased in quantity but somewhat gained in price, and woollen piece goods, though increasing 13 per cent. in quantity have fallen 4 per cent. in price.

Taking the whole of the exports together, these figures establish the fact that the very low prices of manufactured goods which prevailed in the latter part of 1878 and the earlier part of 1879, have continued to rule since that time; and that for very nearly all the addition to the values of that which left our shores before the revival, we have had to give extra quantities, the advantage in point of prices obtained having been inconsiderable. If, therefore, the business of selling has yielded any better return, it must have been because the manufacturer received less; and if the manufacturer gained at all, it must have been either from the lesser value of money or a reduction in the wages of his labourers. Further, as will be shown in dealing with the imports, in the cost of the raw materials from abroad from which most of our textile fabrics are woven there has been, especially in cotton, a decided increase.

Turning now to the imports, and separating those retained at home from those re-exported, we find a total value of about 347,000,000*l.*, as against 293,000,000*l.* in 1879. Abstracting, as with the exports, the chief articles, and classifying them according to their uses, the following figures present themselves:—

	Value of Imports, 1879–80	More or less than 1878–79	Increase or Decrease due to	
			Quantity	Price
	£	£	£	£
Meat, live and dead	23·72	4·06	3·70	·36
Butter and cheese	15·34	1·18	1·15	·03
Corn and flour	64·35	13·96	6·32	7·64
Potatoes	3·68	1·93	1·95	–·02
Coffee, tea, and sugar	32·66	·26	–·68	·94
Spirits and wine	8·24	1·69	1·18	·51
Tobacco	1·95	–·58	–·18	–·40
Food	149·94	22·50	13·44	9·06
Cotton, raw	37·63	10·50	7·21	3·29
Flax, hemp, and jute	9·31	2·66	2·03	·63
Silk, raw	2·64	·76	·92	–·16
Wool, sheep's	11·77	1·79	2·02	–·23
Textile	61·35	15·71	12·18	3·53
Iron, ore and manufactured	5·80	1·86	1·78	·08
Copper	4·13	·34	—	·34
Wood	12·38	2·03	2·28	–·25
Hides and leather	5·02	1·36	1·03	·33
Metals, &c.	27·33	5·59	5·09	·50
Total specified	238·62	43·80	30·71	13·09

As with the exports, these selected articles form about two-thirds of the whole of the importations retained for home consumption or manufacture—namely, 238 millions out of 347; but they absorb more than that proportion of the increase over the previous year—namely 44 out of 54, which is equal to four-fifths.

Coming to details, it will be seen that this increase of 43·80 is $22\frac{1}{2}$ per cent. on the value of the previous year, whereas on the exports it was not much more than 15 per cent., from which it is clear that the value of the additional goods received for home use has exceeded that of the deliveries for sale abroad in the proportion of very nearly 3 to 2. Of this amount 30·71*l.*, or 70 per cent., is owing to the quantities having been greater, and 13·09*l.*, or 30 per cent., from better prices having been obtained.

The first division in the foregoing table, consisting of food, with which are included beverages and tobacco, is by far the largest, taking more than one-half of the articles—150 millions out of 239; and its share of the increase for the year is nearly in the same proportion ($22\frac{1}{2}$ out of 44), the increase itself being $17\frac{1}{2}$ per cent. beyond last year's supplies. In the raw material for textile manufactures—61·35*l.*, which is rather more than a fourth of the whole, shows an increase over last year of 15·71*l.*, equal to 34 per cent. In the remaining class, including the principal metals, wood and leather, 27·33*l.*, comprising one-sixth of the whole, the increase in the year is 5·59*l.*, or 26 per cent. Dividing then the surplus between volume and value, it appears that the increase of food has been 60 per cent., in textile materials 77 per cent., and in the others 91 per cent. on the quantities. So, in respect to the prices paid, which have been 40 per cent. on food, 23 on textile materials, and 9 per cent. on metals, &c.

It needs no very close observation of these figures to discover the marked contrast they present to those for the exports—in that, whilst those showed the rise of prices to have been comparatively little, these manifest a decided advance, particularly in almost every article of food proper. We have not only consumed more, but that consumption has been more costly, as well as more abundant. In proof that this is really the case, two articles may be singled out, sharing between them in nearly equal portions rather more than half the whole increase in outlay. These are wheat—the food for the body, that on which more than on anything else we depend for the power to manufacture; and cotton, the food for our mills, on which vastly more than on any other article we depend for the maintenance of our power to produce that which we can exchange for food. Of wheat we have consumed within the year, or are storing up for consumption, that which has cost us 12,000,000*l.* more than in the previous year; and of this amount 7,000,000*l.* has been spent because our growth at home was deficient in quantity, and 5,000,000*l.* because that deficiency enhanced the price the consumers have had to pay. Of cotton wool we have imported and kept that which has cost us 10,500,000*l.*; and of this 7,250,000*l.* has gone to provide the additional weight, and 3,250,000*l.* the extra price at which it has been procured. Of this additional cotton as nearly as possible one-half has gone away again in the shape of manufactured goods, the other half being added to the stocks on hand, or consumed for home purposes.

Thus far we have been considering the articles in which the country has traded, and the money value they represent; but an important branch of the inquiry relates to the countries with which that trade has been

carried on, and the altered conditions in which it stands. The figures that may serve to illustrate these points are not so complete as those with which we have been dealing, for it is only at the close of each year that the necessary accounts are published, and these do not show the transactions of the respective months which must form a portion of any period ending otherwise than on December 31. The quarterly accounts furnish materials for compiling the value of the whole imports for the twelvemonth ending in June, but not for those re-exported; and those for the exports contain only the values of British produce and manufacture. From these data, however, it is possible to obtain a pretty clear idea of the directions which the trade has been taking, and the differences between its progress during each of the twelvemonths completed on June 30, 1879 and 1880.

The following is a condensed account of the value of the United Kingdom manufactures which have been exported to the British possessions and foreign countries.

	1879–80	1878–79	Excess of former
	£	£	£
To British India	28·68	23·39	5·29
" Africa	8·46	8·05	·41
" Australia	15·48	18·46	−2·98
" North America	6·50	5·70	·80
Other Possessions	8·67	7·53	1·14
	67·79	63·13	4·66
To Foreign Countries in Europe	79·88	80·72	−·84
" " Asia	11·20	8·78	2·42
" " Africa	4·26	3·97	·29
" United States of America	30·49	15·14	15·35
" Other Countries in ditto	17·05	16·43	·62
	142·88	125·04	17·84
Total to British Possessions and Foreign Countries	210·67	188·17	22·50

If we except Australia, to which there has been so marked a decline—the effect, doubtless, of her protective tariff—the only countries that show a great difference in the two years—and these both in the way of increase—are British India and the United States of America. India has taken from us in cotton yarn and piece goods to the value of 18·99*l.* against 14·72*l.*, thus nearly accounting for the above excess, and going far towards repaying us for the raw cotton purchased from her. The United States have drawn upon us for iron and other metals to the value of 11·03*l.* against 3·14*l.*, and for cotton and other textiles 9·56*l.* against 5·34*l.*, thus more than returning the increased sums paid by us for her wheat and flour.

Following the same arrangement, the imports for the same period show thus:—

	1879–80	1878–79	Excess of former
	£	£	£
From British India	35·51	31·64	3·87
" Africa	6·67	6·01	·66
" Australia	23·26	22·80	·46
" North America	10·69	9·71	·98
Other Possessions	10·30	8·42	1·88
	86·43	78·58	7·85
From Foreign Countries of Europe	161·88	146·50	15·38
" " Asia	17·35	16·23	1·12
" " Africa	14·19	8·67	5·52
" United States of America	100·92	81·63	19·29
" Other Countries in "	20·62	19·74	·88
	314·96	272·77	42·19
Total from British Possessions and Foreign Countries	401·39	351·35	50·04

These figures indicate that the expansion of our import trade has been a benefit to almost every country, though here India and the United States, with Egypt, have been the most prominent. In all these the two great articles of corn and cotton have had the principal part. That with the various countries of Europe is so large that a slight addition to each, arising in great measure from our demands for corn, makes up a considerable total. The chief interest, however, centres in the supplies we have drawn from the United States. Wheat and flour together amounted in 1878–9 to 17·46*l.*, and in 1879–80 to 26·58*l.*; cotton to 22·68*l.* in the former, to 28·37*l.* in the latter.

The analysis to which these figures have been submitted serves to bring out many points of especial interest connected with the present revival, and should afford much food for thought as regards its probable course and duration.

In the first place, it shows that, great as has been the increase in our exportations, that in our import trade is far greater. If we have sold in the last twelve months to the value of 32,000,000*l.* more than we did in the previous twelve, we have also received more goods to the value of 59,000,000*l.*, thus leaving a greater balance to be provided for. No doubt a considerable portion of that 27,000,000*l.* will remain with us in payment for freights, commissions earned, or profits realised; but an ample allowance for these must still leave a large amount to be met either by payments in bullion, the transfer of securities, or as deferred obligations. Nor must it be forgotten that there is a continual stream of capital flowing from this country for investment in our colonies and in foreign lands, which going out mostly in goods, or in bills which serve as payment for goods, the actual receipts for our exports are lessened thereby. There is, on the other hand, capital returning for investment here, which in like manner is represented by imports; but all our experience justifies the supposition that the influx from this cause is less than the efflux. Much of the former is held here on foreign account, liable at any moment to be withdrawn;

hence the doubts so freely expressed at the present moment whether a drain of gold may not soon set in.

Secondly, it is evident that on the whole the prices obtained for our exports are only to a trifling extent better than they were, whilst the prices paid for our imports are considerably enhanced. Thus the revival has been much more to the advantage of the sellers of the goods we have consumed than to that of those who sold our own produce or manufacture. In the complicated state of trade transactions it is impossible to say whether any or how much of this advantage belongs to our merchants, since this depends upon the ownership at the time when the sales are effected. As between the actual producers and consumers it is clear that a higher rate of payments for imports, with nearly stationary receipts for exports, cannot increase the prosperity of either one or the other. It would seem to be the case that sales are effected because prices are low, and that purchases are made because we need them although prices are high. Take, for instance, the fact that the cotton used up in the manufacture of our piece-goods has failed to bring in the higher price which the advanced cost of the raw material would justify or require.

Thirdly, the whole excess in the value of the exports is scarcely equivalent to the extra cost of the food we have imported. Unless we can suppose that large stocks of produce and manufacture, or the means of producing them, are prepared for future sale, in readiness to obtain a profit when parted with, it follows that, as a whole, all the gain of extended foreign outward trade has but gone in the sustenance of those by whom the goods have been produced, leaving nothing wherewith to recompense capital or for the accumulation of wealth.

This brings us to the really important consideration whether the food question is not truly at the bottom of the recent fluctuations in trade. For a series of years our own supplies have been scanty, and the bad harvest of last year rendered us more than ever dependent upon the produce of foreign countries, particularly of America. Purchasing largely from the Western growers, and giving them remunerative prices, they have large profits to expend upon our manufactures. Encouraged by the successive annually increasing quantities they were able to sell, they have been laying themselves out to meet our wants, and, anticipating an ever-growing call for their produce, they have determined by means of new railways to bring larger quantities, and at lesser cost, from the distant fields in the West to the seaboard in the East. Hence the sudden demand for rails and for the iron to make them which the pits and the mills of their own country could not supply, but which the diminution of prices here enabled them to obtain sufficiently low to counteract the otherwise prohibitory duties of their own tariff. Trade thus started in one direction speedily spread in others, and thus extended far beyond the boundaries in which it emanated. The repeated adversities of former years have caused the depression of 1878–9 to be greater than the causes warranted, and with the changes of last autumn confidence became restored, and this of itself creates trade.

The supposition that this revival is greatly owing to the failure of our home crops derives much confirmation from the fact, that whilst the best authorities estimate the diminished growth of wheat last year at from five to six million quarters, worth some eleven or twelve millions of money, our purchases of corn from the United States alone were fully that amount in excess; to compensate for which they took from us iron and other

metals and textile manufactures together to the value of twelve millions more than in 1878–9. We have here a beautiful illustration of the way in which Nature—rather let us say the Author of Nature's laws, the Divine Ruler, who orders the course of Nature for the welfare of His creatures—counteracts one disturbing element by the restorative power of another. When the fertilising influence of the sun's heat failed us last year, vegetation languished and our fields failed to yield their accustomed supplies. From whence did relief come but from the latent heat, which ages back became imprisoned in the depths of our coal-pits, being brought forth and utilised for the production of those manufactures wherewith we purchased corn elsewhere? Where can we look for a more convincing argument in favour of free trade than is to be found in the blessings it procured for us in permitting this unrestricted exchange of the commodities absolutely necessary to our existence, and of special importance to our brethren in America? Whilst we sympathise with our agriculturists in the loss of their substance and the severe trials which they are enduring, let us rejoice that the evil was stayed from spreading to our manufacturers and traders, and thereby involving them in the like suffering. Let us not, however, be led away by undue expectations for the future. A good harvest at home—still more a succession of them, if combined with greater productiveness abroad—would so far depress prices as to lessen the purchasing power of the food-growers at home, whilst we shall not need to buy so largely from abroad. Thus those who have latterly supported our markets will fail to purchase as they have done, and if our manufacturing industries are to be sustained we must not rely on a repetition of the demands that have latterly been made upon them.

There is too much danger at present that we shall drawn into wild speculations and expectations, such as led up to the fictitious prosperity of seven years back, and culminated in the depression of more recent years. Let us not delude ourselves with the belief that the inflation of 1871–3 is about to return—that fortunes are going to be made as rapidly as then, or wages to rise to the same level. Let us not, however, give way to gloomy fears. Cheap food will foster cheap production, and, though our old customers may under its influence be enabled to supply their own wants, there are new races of purchasers to be found or called into being, and new homes to be founded by those who are cumbering the ground here rather than tilling it in the distant parts of the Empire. The judicious transferal of much of our capital and labour to places abroad, where there is ample room for its profitable employment, together with greater thrift—individual, family, and national—at home, are the true sources on which to rely for the maintenance or restoration of our manufacturing and commercial supremacy.

TRANSACTIONS OF THE SECTIONS.

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Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—Professor W. Grylls Adams, M.A., F.R.S., F.G.S., F.C.P.S.

THURSDAY, AUGUST 26.

The President delivered the following Address :—

It has been said by a former President of this Section of the British Association that the President of a Section ought to occupy your time, not by speaking of himself or his own feelings, but by a review 'more or less extensive of those branches of science which form the proper business of this section.' He may give a rapid sketch of the progress of mathematical science during the year, or he may select some one special subject, or he may take a middle course, neither so extensive as the first nor so limited as the second.

There are many branches of science which have always been regarded as properly belonging to our Section, and the range is already wide; but it is becoming more and more true every day that the sciences which are dealt with in other sections of the Association are becoming branches of Physics, *i.e.* are yielding results of vast importance when the methods and established principles of Physics are applied to them. I wish to direct your attention to investigations which are being made in that fertile region for discovery, the 'border land' between chemistry and physics, where we have to deal with the constitution of bodies, and where we are tempted to speculate on the existence of matter and on the nature of the forces by which the different parts of it are bound together or become so transformed that all resemblance to their former state is lost. It is not long since the theory of exchanges became thoroughly recognised in the domain of Radiant Heat, and yet so rapid is the progress of science that it is already recognised and accepted in the theory of Chemical combination. Just as the molecules of a body which remains at a constant temperature are continuously giving up their heat-motion to surrounding molecules, and getting back from them as much motion of the same kind in return, so in a chemical compound which does not appear to be undergoing change, the combining molecules are continuously giving up their chemical or combining motions to surrounding molecules, and receiving again from them as much combining motion in return. We may say that each molecule is, as far as we can see, constantly dancing in perfect time with a partner, and yet is continuously changing partners. When such an idea of chemical motion is accepted, we can the more easily understand that chemical combination means the alteration of chemical motion, which arises from the introduction of a new element into the space already occupied, and the consequent change in the motion of the new compound as revealed to us in the spectroscope. We can also the more readily understand that in changing from the old to the new form or rate of motion, there may be a development of energy in the shape of heat-motion which may escape or become dissipated wherever a means of escape presents itself. We know from the experiments of Dr. Joule and of M. Favre that as much heat is absorbed during the decomposition of an electrolyte as is given out again by the combination of the substances composing it.

We are making rapid strides towards the exact determination of those relations between the various modes of motion or forms of energy which were so ably shadowed forth, and their existence established long ago, by Sir William Grove in his 'Correlation of the Physical Forces,' where, in stating the conclusion of his comparison of the mutual interchange of physical forces, he distinctly lays down the principles of energy in this statement: 'Each force is definitely and equivalently convertible into any other; and where experiment does not give the full equivalent, it is because the initial force has been dissipated, not lost, by conversion into other unrecognised forces. The equivalent is the limit never practically reached.'

The laws of Faraday, that (1) when a compound is electrolysed the mass of the substance decomposed is proportional to the quantity of electricity which has produced the change, and that (2) the same current decomposes equivalent quantities of different substances, *i.e.* quantities of their elements in the ratio of their combining numbers, have given rise to several determinations of the relation between chemical affinity and electromotive force. In a paper lately communicated to the Physical Society, Dr. Wright has discussed these several determinations, and has given an account of a new determination by himself. The data at present extant show that when 1 gramme of hydrogen unites with 7·98 grammes of oxygen there are about 34,100 units of heat given out, making the latent heat of dissociation of 1 gramme of water equal to 3797 units. The results obtained are compared with the heat given out by the combustion of hydrogen and oxygen, and the value of the mechanical equivalent of heat is deduced from these determinations.

The value of this mechanical equivalent obtained by Dr. Wright, which depends on the value of Clark's standard cell, and therefore depends on the value of the ohm, agrees fairly well with Joule's determination from the heat produced by an electric current in a wire, but is greater than Joule's value as obtained from his water-friction experiments. This may be accounted for by supposing an error in the value of the ohm or B.A. unit, making it too large by 1·5 or 2 per cent. Kohlrausch has also made comparisons of copies of the B.A. unit with standard coils, and comes to the conclusion that the B.A. unit is 1·96 per cent. too large. On the other hand, Professor Rowland, in America, has made a new determination, and finds that according to his calculations the B.A. unit is nearly 1 per cent. too small. These differences in the values obtained by different methods clearly point to the necessity for one or more new determinations of the unit, and I would venture to suggest that a determination should be made under the authority of this Association, by a Committee appointed to carry out the work. And it is not sufficient that this determination should be made once for all, for there is reason to think that the resistance of standard coils alters with time, even when the material has been carefully selected. It has been found that coils of platinum silver which were correct copies of the standard ohm have become so altered, and have their temperature coefficients so changed, that there are doubts as to the constancy of the standards themselves. Pieces of platinum-silver alloy cut from the same rod have been found to have different temperature-coefficients. The value ·031 for 1° C. is given by Matthiessen for this alloy, yet two pieces of wire drawn from the same rod have given, one ·021 per cent. and the other ·04 per cent. for 1° C. Possibly this irregularity in the platinum-silver alloys may be due to something analogous to the segregation which Mr. Roberts has found to take place in copper-silver alloys in their molten state, and which Matthiessen in 1860 regarded as mechanical mixtures of allotropic modifications of the alloy.

A recommendation has been made that apparatus for determining the ohm should be set up in London, and that periodically determinations be made to test the electrical constancy of the metals and alloys used in making coils. A committee should be authorised to test coils and issue certificates of their accuracy, just as is done by the Kew Committee with regard to meteorological instruments. The direct relation between Heat and Chemical work has been established, and the principles of Conservation of Energy been shown to be true in Chemistry by the experiments of Berthelot and of Thomsen, so that we may say that when a system of bodies passes through any succession of chemical changes, the heat evolved or absorbed when no external mechanical effect is produced depends solely upon the

initial and final states of the system of bodies, whatever be the nature or the order of the transformations. The extension of this principle to the interaction of the molecules and atoms of bodies on one another is of vast importance in relation to our knowledge of the constitution of matter, for it enables us to state that each chemical compound has a distinct level or potential which may be called its own, and that when a compound gives up one of its elements to another body, the heat evolved in the reaction is the difference between the heat of formation of the first compound, and that of the resulting product.

We have become accustomed to regard matter as made up of molecules, and those molecules to be made up of atoms separated from one another by distances which are great in comparison with the size of the atom, which we may regard as the smallest piece of matter that we can have any conception of. Each atom has been supposed to be surrounded by an envelope of ether which accompanies it in all its movements. The density of the ether increases rapidly as an atom is approached, and it would seem that there must be some force of attraction between the atom and its ether envelope. All the atoms have motions of translation in all possible directions, and according to the theories of Maxwell and Boltzmann, and the experiments of Kundt, Warburg, and others on the specific heat of vapours, in *one-atom* molecules in the gaseous state there is no motion of rotation. According to the theory of Pictet, the liquid state being the first condensation from the gaseous state must consist of at least two gaseous atoms combined. These two atoms are bound to one another through their ether envelopes. Then the solid state results from the condensation of a liquid, and so a solid molecule must consist of at least two liquid molecules, *i.e.* at least four gaseous molecules, each surrounded by an atmosphere of ether. M. Pictet imagines these atoms to be centres of attraction; hence in the solid with four such centres the least displacement brings into action couples tending to prevent the molecule from twisting as soon as external forces act upon it. All the molecules constituting a solid will be rigidly set with regard to one another, for the least displacement sets in action a couple or an opposing force in the molecules on one another.

Let us now follow the sketch which M. Pictet has given of changes which we may consider it to undergo when we expend energy upon it. Suppose a solid body is at absolute zero of temperature, which may be regarded as the state in which the molecules of a body are in stable equilibrium and at rest, the application of heat gives a vibratory motion to the molecules of the solid, which increases with the temperature, the mean amplitude of vibration being a measure of the temperature. We may regard the sum of all the molecular forces as the specific heat of the body, and the product of the sum of all the molecular forces by the mean amplitude of the oscillations; *i.e.* the product of the specific heat and the temperature will be the quantity of heat or the energy of motion of the body. As more and more heat is applied, the amplitude of vibration of the molecules increases until it is too great for the molecular forces, or forces of cohesion, and the melting point of the solid is reached. Besides their vibratory motion, the molecules are now capable of motions of translation from place to place among one another. To reduce the solid to the liquid state, *i.e.* to make the amplitude of vibration of the molecules sufficient to prevent them from coming within the sphere of the forces of cohesion, requires a quantity of heat which does not appear as temperature or molecular motion, and hence it is termed the latent heat of fusion. The temperature remains constant until the melting is complete, the heat being spent in bursting the bonds of the solid. Then a further application of heat increases the amplitude of vibration, or raises the temperature of the liquid at a rate depending on its specific heat until the succession of blows of the molecules overcomes the external pressure and the boiling point is reached. An additional quantity of heat is applied which is spent in changing the body to a gas, *i.e.* to a state of higher potential, in which the motion of translation of the molecules is enormously increased. When this state is attained, the temperature of the gas again begins to increase, as heat is applied, until we arrive at a certain point, when dissociation begins, and the molecules of the separate substances of which the body is composed have so large an amplitude of vibration that the bond which unites them can no longer bring them again into their former positions.

The potential of the substances is again raised by a quantity which is proportional to its chemical affinity. Again, we may increase the amplitude of vibration, *i.e.* the temperature of the molecules, and imagine the possibility of getting higher and higher degrees of dissociation.

If temperature means the amplitude of vibration of the molecules, then we might expect that only those bodies which have their temperatures increased by the same amount when equal amounts of heat are applied to them can possibly combine with one another; and so the fact that the increase of temperature bears a fixed ratio to the increase of heat may be the cause in virtue of which bodies can combine with one another. Were other bodies to begin to combine together at any definite temperature, they would immediately be torn to pieces again when the temperature is even slightly raised, because the amplitudes of vibration of their molecules no longer remain the same. This idea of temperature is supported by the fact that a combining molecule of each substance requires the same amount of heat to raise its temperature by the same number of degrees, the atomic weights being proportional to the masses of the combining molecules. The celebrated discovery of Faraday, that in a voltameter the work done by an electric current always decomposes equivalent quantities of different substances, combined with the fact that in the whole range of the physical forces work done is equivalent to the application of heat, is quite in accordance with the view that no molecule can combine with another which has not its amplitude of vibration altered by the same amount when equal quantities of heat are applied to both. As soon as we get any divergence from this state of equal motions for equal increments of heat, then we should expect that a further dissociation of molecules would take place, and that only those which are capable of moving together can remain still associated.

Just as in the change of state of a body from the solid to the liquid, or from the liquid to the gas, a great amount of heat is spent in increasing the motion of translation of the molecules without altering the temperature, so a great amount of heat is spent in producing dissociation without increasing the temperature of the dissociated substances, since the principle of conservation of energy has been shown by M. Berthelot to hold for the dissociation of bodies. We may conveniently make use of the term latent heat of dissociation for the heat required to dissociate a unit of mass of a substance.

We may thus sum up the laws of physical and chemical changes:—

1. All the physical phenomena of change of state consist in the subdivision of the body into molecules or particles identical with one another.

2. The reconstitution of a body into a liquid or a solid being independent of the relative position of the molecules, only depends on the pressure and temperature.

3. Dissociation separates bodies into their elements, which are of different kinds, and the temperature remains constant during dissociation.

4. The reunion of dissociated bodies depends on the relative position of the elements, and so depends on the grouping of the molecules. The atomic weight being the mass of a molecule as compared with hydrogen, the specific volume, *i.e.* the atomic weight divided by the density, is the volume or *mean free path* of a molecule.

Building up his theory of heat on these principles, M. Pictet arrives at a definite relation between the atomic weight of a body, its density, its melting point, and its coefficient of expansion, which may be stated thus—

The volume of a solid body will be increased as the temperature rises by an amount which is proportional to the number of molecules in it, and inversely as its specific heat. At a certain temperature peculiar to each body, the amplitude of the heat oscillation is sufficient to melt the solid, and we are led to admit that for all bodies the intermolecular distance corresponding to fusion ought to be the same. The higher the point of fusion of a body, the shorter, on this theory, must be its heat-vibrations. The product of the length of *swing* (the heat-oscillations) by the temperature of fusion ought to be a constant number for all solid bodies.

A comparison of the values of the various quantities involved in these statements shows a very satisfactory agreement between theory and experiment, from which it appears that the product of the length of swing by the temperature of

fusion lies between 3·3 and 3·7 for many substances. Not many values of the latent heat of dissociation have been obtained. In order to determine it, say, for the separation of oxygen and hydrogen, we should have to determine the amount of work required to produce a spark in a mixture of oxygen and hydrogen, and to measure the exact amount of water or vapour of water combined by the spark, as well as the range of temperature through which it had passed after its formation. Very few such determinations have been made.

Our usual mode of producing heat is by the combination of the molecules of different substances, and we are limited in the production of high temperatures, and in the quantity of available heat necessary to dissociate any considerable quantity of matter. If we heat vapours or gases, we may raise their temperatures up to a point corresponding to the dissociation of their molecules, and we are limited in our chemical actions to the temperatures which can be obtained by combining together the most refractory substances, as we are dependent on this combination for our supply of heat.

The combination of carbon and hydrogen with oxygen will give us high temperatures, so that by the oxyhydrogen blow-pipe most of the salts and oxides are dissociated. The metalloids bromine, iodine, sulphur, potassium, &c., are the results of the combination of two or more bodies bound together by internal forces much stronger than the affinity of hydrogen or carbon for oxygen, for approximately they obey the law of Dulong and Petit.

For higher temperatures, in order to dissociate the most refractory substances, we require the electric current, either a continuous current, as in the electric arc from a battery, or a dynamo-machine, or, more intense still, the electrical discharges from an electrical machine or from an induction coil.

This electric current may be regarded as the most intense furnace for dissociating large quantities of the most refractory substances, and the electric spark may be regarded as something very much hotter than the oxyhydrogen blow-pipe, and therefore of service in reducing very small quantities of substances which will yield to no other treatment. The temperature of the electric arc is limited, and cannot reach above the temperature of dissociation of the conductor, and in the case of the constant current, which will not leap across the smallest space of air unless the carbons have first been brought in contact, the current very soon ceases when the point of fusion has been reached. Yet in the centre of the arc we have the gases of those substances which form the conductor; and, as Professor Dewar has shown, we have the formation of acetylene and cyanogen and other compounds, and therefore must have attained the temperature necessary for their formation, *i.e.* the temperature of their dissociation. The temperature of the induction spark, or, at least, its dissociating power, is higher than that of the arc. We know that the spark will pass across a space of air or a gaseous conductor, and we are limited by the dissociation of the gaseous conductor, and get only very small quantities of the dissociated substances, which immediately recombine, unless they are separated. If the gases formed are of different densities they will diffuse at different rates through a porous diaphragm, and so may be obtained separated from one another. As the molecules of bodies vibrate they produce vibrations of the ether particles; the period of the oscillations depends on the molecules of the body, and these periodic vibrations are taken up by their ether envelopes and by the luminiferous ether, and their wave-length determined by means of the spectroscope. As the temperature is increased, the amplitudes of oscillation of the molecules and of the ether increase, and from the calculations of Lecoq de Boisbaudran, Stoney, Soret, and others, it would appear that many of the lines in the spectra of bodies may be regarded as harmonics of a fundamental vibration. Thus Lecoq de Boisbaudran finds that in the nitrogen spectrum the blue lines seen at a high temperature correspond to the double octave of certain vibrations, and that, at a lower temperature, red and yellow lines are seen which correspond to a fifth of the same fundamental vibrations.

The bright line spectrum may be regarded as arising from the vibratory motions of the atoms. A widening of the lines may be produced at a higher temperature by the backward and forward motions of the molecules in the direction of the

observer. A widening of the lines may also be produced by increase of pressure, because it diminishes the free path of the molecules, and the disturbances of the ether arising from collisions become more important than vibrations arising from the regular vibrations of the atoms.

Band spectra, or channelled space spectra, more readily occur in the case of bodies which are not very readily subject to chemical actions, or, according to Professors Liveing and Dewar, in the case of cooler vapours near the point of liquefaction.

The effects of change of temperature on the character of spectra is very well illustrated by an experiment of M. Wiedemann with mixtures of mercury with hydrogen or nitrogen in a Geissler's tube. At the ordinary temperature of the air the spectrum of hydrogen or nitrogen was obtained alone; but on heating the tube in an air-bath the lines of mercury appeared and became brighter as the temperature rose, and at the same time the hydrogen lines disappeared in the wider portion of the tube and at the electrodes. The hydrogen or nitrogen lines disappeared first from the positive electrode and in the luminous tuft, and as the temperature rose disappeared altogether. With nitrogen in a particular experiment, up to 100° C., the nitrogen lines were seen throughout the tube, but from 100° to 230° the nitrogen lines appear towards the negative pole, and the mercury lines are less bright at the negative than at the positive pole, while at about 230° C. no nitrogen lines appear. The experiments of Roscoe and Schuster, of Lockyer and other observers, with potassium, sodium, and other metalloids in vacuum tubes, from which hydrogen is pumped by a Sprengel pump, also show great changes in the molecular condition of the mixture contained in the tubes when they are heated to different temperatures. The changes of colour in the tube are accompanied by changes in the spectrum. Thus, Mr. Lockyer finds that when potassium is placed in the bottom of the tube, and the spark passes in the upper part of it, as the exhaustion proceeds and the tube is slightly heated, the hydrogen lines disappear, and the red potassium line makes its appearance; then as the temperature is increased, the red line disappears, and three lines in the yellowish-green make their appearance, accompanied by a change in the colour of the tube, and at a higher temperature, and with a Leyden jar joined to a secondary circuit of the induction coil, the gas in the tube becomes of a dull red colour, and with this change a strong line comes out in the spectrum, more refrangible than the usual red potassium line. In this case, on varying the conditions, we get a variation in the character of the spectrum, and the colours and spectra are different in different parts of the tube. In Lockyer's experiments, at the temperature of the arc obtained from a Siemens dynamo-machine, great differences appear in different parts of the arc: for instance, with carbon poles in the presence of calcium, the band spectrum of carbon, or the carbon flutings and the lines of calcium, some of them reversed, are seen separated in the same way as mercury and hydrogen, the carbon spectrum appearing near one pole and the calcium near the other, the lines which are strongest near that pole being reversed or absorbed by the quantity of calcium vapour surrounding it. On introducing a metal into the arc, lines appear which are of different intensities at different distances from the poles, others are strong at one pole and entirely absent at or near the other, while some lines appear as broad as half-spindles in the middle of the arc, but are not present near the poles. Thus, the blue line of calcium is visible alone at one pole, the H and K lines without the blue line at the other.

We may probably regard these effects as the result, not of temperature alone, but must take into account that we have powerful electric currents which will act unequally on the molecules of different bodies according as they are more or less electro-positive. It would seem that we have here something analogous to the segregation which is observed in the melting of certain alloys to which I have already referred.

The abundance of material in some parts of the arc surrounding the central portion of it gives rise to reversal of the principal lines in varying thicknesses over the arc and poles, so that bright lines appear without reversal in some regions, and reversals or absorption lines without bright lines in others. The introduction of a substance into the arc gives rise to a flame of great complexity with regard to colour

and concentric envelopes, and the spectra of these flames differ in different parts of the arc. Thus, in a photograph of the flame given by manganese, the line at wave-length 4234·5 occurs without the triplet near 4030, while in another the triplet is present without the line 4234·5.

The lines which are reversed most readily in the arc are generally those the absorption of which is most developed in the flame; thus the manganese triplet in the violet is reversed in the flame, and the blue calcium line is often seen widened when the H and K lines of calcium are not seen at all. In consequence of the numerous changes in spectra at different temperatures, Mr. Lockyer has advanced the idea that the molecules of elementary matter are continually being more and more broken up as their temperature is increased, and has put forward the hypothesis that the chemical elements with which we are acquainted are not simple bodies, but are themselves compounds of some other more simple substances. This theory is founded on Mr. Lockyer's comparisons of spectra and the maps of Ångstrom, Thalèn, Young, and others, in which there are coincidences of many of the short lines of the spectra of different substances. These short lines are termed basic lines, since they appear to be common to two or more substances. They appear at the highest temperatures when the longest lines of those substances and those which are considered the test of their presence are entirely absent.

Mr. Lockyer draws a distinction between weak lines, which are basic, *i.e.* which would permanently exist at a higher temperature in a more elementary stage, and other weak or short lines which would be more strongly present at a lower temperature, in a more complex stage of the molecules. Thus, in lithium, the red line is a low temperature line, and the yellow is feeble; at a higher temperature, the red line is weak, the yellow comes out more strongly, and the blue line appears; at a higher temperature still, the red line disappears, and the yellow dies away; whilst at the temperature of the sun the violet lithium line is the only one which comes out strongly. These effects are studied by first producing the spectrum of the substance in the Bunsen flames, and observing the changes which are produced on passing a spark through the flame; thus, in magnesium a wide triplet or set of three lines (5209·8, b^1 and b^2) is changed into a narrow triplet (b^1, b^2, and b^4) of the same character. We have here what some observers regard as a recurrence of the same harmonic relation of the vibrations of the same body at a higher temperature.

If the so-called elements are compounds, they must have been formed at a very high temperature, and as higher and higher temperatures are reached the dissociation of these compound bodies will be effected, and the new line spectra, the real basic lines of those substances which show coincidences, will make their appearance as short lines in the spectra. In accordance with this view, Mr. Lockyer holds that the different layers of the solar atmosphere may be regarded as a series of furnaces, in the hottest of which, A, we have the most elementary forms of matter capable of existing only in its uncombined state; at a higher and cooler level, B, this form of matter may form a compound body, and may no longer exist in a free state at the lower temperature; as the cooler and cooler levels, C, D, and E, are reached, the substances become more and more complex and form different combinations, and their spectra become altered at every stage. Since the successive layers are not at rest, but in a state of disturbance, we may get them somewhat mixed, and the lines at the cooler levels D and E may be associated with the lines of the hotter levels; these would be basic or coincident lines in the spectra of two different compounds which exist at the cooler levels D and E. We might even get lines which are not present in the hottest furnace A coming into existence as the lines of compounds in B or C, and then extending among the lines belonging to more complex compounds which can only exist at a lower temperature, when they might be present as coincident weak lines in the spectra of several compound bodies. Thus Mr. Lockyer regards the calcium lines H and K of the solar spectrum as evidence of different molecular groupings of more elementary bodies. In the electric arc with a weak current the single line 4226 of calcium, which is easily reversed, is much thicker than the two lines H and K; but the three lines are equally thick with a stronger current, and are all reversed. With a spark from a large coil and using a condenser the line 4226 disappears, and H and K are

strong lines. In the sun, the absorption bands H and K are very broad, but the band 4226 is weak. Prof. Young, in his observation of the lines of the chromosphere, finds that H and K are strongly reversed in every important spot and in solar storms; but the line 4226, so prominent in the arc, was only observed three times in the chromosphere.

One of the most interesting features among the most recent researches in Spectrum Analysis is the existence of rhythm in the spectra of bodies, as has been shown by M. Mascart, Cornu, and others, such as the occurrence and repetition of sets of lines, doublets, and triplets in the spectra of different substances and in different parts of the spectrum of the same body. Professors Liveing and Dewar, using the reversed lines in some cases for the more accurate determination of wave-lengths, have traced out the rhythmical character in the spectra of sodium, potassium, and lithium. They show that the lines of sodium and potassium form groups of four lines each, which recur in a regular sequence, while lithium gives single lines, which, including the green line, which they show really to belong to lithium, though it was ascribed to cæsium by Thalèn, also recur in a similar way. In these three metals the law of recurrence seems to be the same, but the wave-lengths show that the whole series are not simple harmonics of one fundamental, although between some of the terms very simple harmonic relations can be found. Between the lines G and H are two triplets of iron lines, which, according to Mr. Lockyer, do not belong to the same molecular grouping as most of the other lines. In many photographs of the iron spectrum these triplets have appeared almost alone. Also the two triplets are not always in the same relation as to brightness, the more refrangible being barely visible with the spark; combining this with Young's observations, in which some short weak lines near G appear in the chromosphere 30 times, while one of the lines of the less refrangible triplet only appears once, and with the fact that in the solar spectrum the more refrangible triplet is much the more prominent of the two, Mr. Lockyer is led to the conclusion that these two triplets are again due to two distinct molecular groupings.

There is one difficulty which must be taken account of in connection with Mr. Lockyer's theory with regard to the production of successive stages of dissociation by means at our command.

At each stage of the process there must be a considerable absorption of heat to produce the change of state, and our supply of heat is limited in the electric arc because of the dissociation of the conductors, and more limited still in quantity in the electric spark or in the discharge through a vacuum tube, also we should expect a recombination of the dissociated substances immediately after they have been first dissociated. Hence it seems easier to suppose that at temperatures which we can command on the earth, the dissociation of molecules by the arc or the spark is accompanied by the formation of new compounds, in the formation of which heat and light, and especially chemical vibrations, would be again given out, giving rise to new spectra, rather than to suppose that we can reach the temperatures necessary for successive stages of dissociation.

To the lines C, F, the line near G, and h belonging to hydrogen, which have a certain rhythmical character, Mr. Lockyer adds D_3 and Kirchoff's line '1474,' regarding '1474' (wave-length 5315·9) as belonging to the coolest or most complex form, rising to F at a higher temperature, which is again subdivided into C and G, using the spark without a condenser, which again gives h with the spark and condenser, which is again split up and gives D_3, a more simple line than h, in the Chromosphere. Professors Liveing and Dewar, on the other hand, trace a rhythmical character or ratio between three of the brightest lines of the chromosphere, two of which are lines '1474' and 'f' of Lorenzoni, similar to the character of C, F, and h of hydrogen, and also trace a similar relation between the chromospheric line D_3 and '1474' to the ratio of the wave-lengths of F and the line near G. They infer the probability that these four lines are due to the same at present unknown substance as had been suggested by Young with regard to two of them. The harmony of this arrangement is somewhat disturbed by the fact that D_3 lies on the wrong side of '1474' to correspond with the line near G of the hydrogen spectrum.

If we inquire what our sun and the stars have to say to these changes of

spectra of the same substance at different temperatures, Dr. Huggins gives us the answer.

In the stars which give a very *white* light, such as Sirius or α Lyræ, we have the lines G and h of hydrogen and also H, which has been lately shown by Dr. Vogel to be coincident with a line of hydrogen; but the K line of calcium is weak in α Lyræ, and does not appear in Sirius. In passing from the white or hottest stars to the yellow stars like our sun, the typical lines diminish in breadth and are better defined, and K becomes stronger relatively to H, and other lines appear. In Arcturus we have a star which is probably cooler than our sun, and in it the line K is stronger in relation to H than it is in the solar spectrum, both being very strong compared with their state in the solar spectrum.

Professors Liveing and Dewar find that K is more easily reversed than H in the electric arc, which agrees with the idea that this line is produced at a lower temperature than H.

Besides the absence or weakness of K, the white stars have twelve strong lines winged at the edges, in which there are three of hydrogen, viz. G, *h*, and H, and the remaining nine form a group which are so related to one another that Dr. Huggins concludes they probably belong to one substance. Three of these lines are said by Dr. Vogel to be lines of hydrogen.

Professors Liveing and Dewar have made considerable progress in determining the conditions and the order of reversal of the spectral lines of metallic vapours. They have adopted methods which allow them to observe through greater thicknesses of vapour than previous observers have generally employed. For lower temperatures tubes of iron or other material placed vertically in a furnace were used, and the hot bottom of the tube was the source of light, the absorption being produced by vapours of metals dropped into the hot tube and filling it to a greater or less height. By this means many of the more volatile metals, such as sodium, thallium, iridium, cæsium, and rubidium, magnesium, lithium, barium, strontium, and calcium, each gave a reversal of its most characteristic line or pair of lines, *i.e.* the red line of lithium, the violet lines of rubidium and calcium, the blue line of strontium, the sharp green line of barium (5535), and no other lines which can certainly be ascribed to those metals in the elementary state.

For higher temperatures tubes bored out in blocks of lime or of gas carbon, and heated by the electric arc, were used. By keeping up a supply of metal and in some cases assisting its volatilisation by the admixture of a more volatile metal, such as magnesium, and its reduction by some easily oxidisable metal, such as aluminium, or by a current of coal gas or hydrogen, they succeeded in maintaining a stream of vapour through the tube so as to reverse a great many lines. In this way the greater part of the bright lines of the metals of the alkalies and alkaline earths were reversed, as well as some of the strongest lines of manganese, aluminium, zinc, cadmium, silver, copper, bismuth, and the two characteristic lines of iridium and of gallium. By passing an iron wire into the arc through a perforated carbon electrode they succeeded in obtaining the reversal of many of the lines of iron. In observing bright line spectra they have found that the arc produced by a De Meritens machine arranged for high tension gives, in an atmosphere of hydrogen, the lines C and F, although the arc of a powerful Siemens machine does not bring them out, and they have observed many metallic lines in the arc which had not been previously noticed. The temperature obtained by the De Meritens machine is thus higher than that obtained in the Siemens machine.

From observations on weighed quantities of sodium, alone and as an amalgam, introduced into a hot bottle of platinum filled with nitrogen, of which the pressure was varied by an air-pump, they conclude that the width of the sodium lines depends rather on the thickness and temperature of the vapour than upon the whole quantity of sodium present. Very minute quantities diffused into the cool part of the tube give a broad diffuse absorption, while a thin layer of compressed vapour in the hot part of the tube give only narrow absorption lines. Professors Liveing and Dewar have observed the reversal of some of the well-known bands of the oxides and chlorides of the alkaline earth metals. The lines produced by magnesium in hydrogen form a rhythmical series extending all across the well-

known B group, having a close resemblance in general character to the series of lines produced by an electric discharge in a vacuum tube of olefiant gas.

The series appears at all temperatures except when a large condenser is employed along with the induction coil, provided hydrogen is present as well as magnesium, while they disappear when hydrogen is excluded, and never appear in dry nitrogen or carbonic oxide.

From their experiments on carbon spectra they conclude with Ångstrom and Thalèn that certain of the so-called 'carbon bands' are due to some compound of carbon with hydrogen, probably acetylene, and that certain others are due to a compound of carbon with nitrogen, probably cyanogen.

They describe some ultra-violet bands: one of them coincides with the shaded band P of the solar spectrum which accompanies the other violet bands in the flame of cyanogen as well as in the arc and spark between carbon electrodes in the nitrogen. All the bands which they ascribe to a compound of carbon and nitrogen disappear when the discharge is taken in a non-nitrogenous gas, and they reappear on the introduction of a minute quantity of nitrogen.

They appear in the flame of hydrocyanic acid, or of cyanogen, even when cooled down as much as possible as shown by Watts, or when raised to the highest temperature by burning the cyanogen in nitric oxide; but no flames appear to give these bands unless the burning substance contains nitrogen already united with carbon. As the views of Mr. Lockyer with regard to the multiple spectra of carbon have very recently appeared in the pages of 'Nature,' I need only say that these spectra are looked upon as supporting his theory that the different flutings are truly due to carbon, and that they represent the vibrations of different molecular groupings. The matter is one of very great interest as regards the spectra of comets, for the bands ascribed to acetylene occur in the spectra of comets without the bands of nitrogen, showing that either hydro-carbons must exist ready formed in the comets, in which case the temperature need not exceed that of an ordinary flame, or else nitrogen must be absent, as the temperature which would produce acetylene from its elements would also produce cyanogen, if nitrogen were present.

Quite recently, Professors Liveing and Dewar have, simultaneously with Dr. Huggins, described an ultra-violet emission spectrum of water, and have given maps of this spectrum. It is not a little remarkable that by independent methods these observers should have deduced the same numbers for the wave-lengths of the two strong lines at the most refrangible end of this spectrum.

Great attention has been paid by M. Mascart and by M. Cornu to the ultra-violet end of the solar spectrum. M. Mascart was able to fix lines in the solar spectrum as far as the line R (3179), but was stopped by the faintness of the photographic impression. Professor Cornu has extended the spectrum still farther to the limit (2948), beyond which no further effect is produced, owing to complete absorption by the earth's atmosphere. A quartz-reflecting prism was used instead of a heliostat. The curvature of the quartz lens was calculated so as to give minimum aberration for a large field of view. The Iceland spa prism was very carefully cut. A lens of quartz was employed to focus the sun on the slit. Having photographed as far as possible by direct solar light, Professor Cornu compared the solar spectrum directly by means of a fluorescent eyepiece with the spectrum of iron, and then obtained, by photography, the exact positions of the iron lines which were coincident with observed lines in the solar spectrum. M. Cornu states that the dark absorption lines in the sun and the bright iron lines of the same refrangibility are of the same relative importance or intensity in their spectra, indicating the equality between the emissive and the absorbing powers of metallic vapours; and he thinks that we may get by the comparison of bright spectra with the sun some rough approximation to the quantity of metallic vapours present in the absorption layers of the sun's atmosphere. He draws attention to the abundance of the magnetic metals—iron, nickel, and magnesium—and to the fact that these substances form the composition of most meteorites. M. Cornu has studied the extent of the ultra-violet end of the spectrum, and finds that it is more extended in winter than in summer, and that, at different elevations, the gain in length of the spectrum for increase of elevation is very slow, on account of atmospheric absorp-

tion, so that we cannot hope greatly to extend the spectrum by taking elevated observing stations. The limit of the solar spectrum is reached very rapidly, and the spectrum is sharply and completely cut off at about the line U (wave-length 2948). From photographs taken at Viesch in the valley of the Rhone and at the Riffelberg, 1910 mètres above it, M. Cornu finds the limits to be at wave-lengths 2950 and 2930 respectively.

In the actual absorption of bright line spectra by the earth's atmosphere, M. Cornu observed among others three bright lines of aluminium, which M. Soret calls 30, 31, and 32 (wave-lengths about 1988, 1930, and 1860), and he found that 32 could not be seen at the distance of 6 mètres; but on using a collimator, and reducing the distance to 1½ mètres, the line 32 became visible, notwithstanding the absorption of the extra lens; at 1 mètre, line 32 was brighter than 31, and at a quarter of a mètre 32 was brighter than either 30 or 31.

With a tube 4 mètres in length between the collimator and prism ray 32 is not seen; but when the tube is exhausted, ray 31 gains in intensity and 32 comes into view, and gradually gets brighter than 31, whilst 30 changes very little during the exhaustion. With the same tube he found no appreciable difference between the absorption by air very carefully dried and by moist air, and concludes that this absorption is not due to the vapour of water, and it follows the law of pressure of the atmosphere which shows it to be due to the whole mass or thickness of the air. Also, M. Soret has shown that water acts very differently on the two ends of the spectrum, distilled water being perfectly transparent for the most refrangible rays, since a column of water of 116 c.m. allowed the ray 2060 in the spectrum of zinc to pass through: on the other hand, water is so opaque to the ultra-red rays that a length of 1 c.m. of it reduces the heat spectra of metals to half their length and one quarter of their intensity.

In concluding my address, I wish to draw attention to some of those magnetic changes which are due to the action of the Sun, and which are probably brought about by means of the ether which conveys to us his radiant heat and light.

In his discussion of the magnetic effects observed on the earth's surface, General Sabine has shown the existence of diurnal variations due to the magnetic action of the sun; also the magnetic disturbances, aurora and earth currents, which are now again beginning to be large and frequent, have been set down to disturbances in the sun.

Although iron, when raised to incandescence, has its power of attracting a magnet very greatly diminished, we have no proof that it has absolutely no magnetic power left, and with a slight magnetic action the quantity of iron in the sun would be sufficient to account for the diurnal variations of the magnetic needle. During the last few weeks I have been engaged in examining the declination curves for the month of March 1879, which have been kindly lent to the Kew Committee by the Directors of the Observatories of St. Petersburg, Vienna, Lisbon, Coimbra, and Stonyhurst. On comparing them with the Kew curves for the the same period, I find the most remarkable coincidences between the curves from these widely distant stations. It was previously known that there was a similarity between disturbances at different stations, and in one or two cases a comparison between Lisbon and Kew had been made many years ago by Señor Capello and Professor Balfour Stewart; but the actual photographic magnetic records from several stations have never been previously collected, and so the opportunity for such comparisons had not arisen. Allow me to draw attention to a few of the more prominent features of these comparisons which I have made. On placing the declination curves over one another, I find that in many cases there is absolute agreement between them, so that the rate of change of magnetic disturbances at widely distant stations like Kew, Vienna, and St. Petersburg is precisely the same; also similar disturbances take place at different stations at the same absolute time. It may be stated generally, for large as well as small disturbances, that the east and west deflections of the declination needle take place at the same time and are of the same character at these widely distant stations.

There are exceptions to this law. Some disturbances occur at one or two stations and are not perceived at another station. Many instances occur where, up to a

certain point of time, the disturbances at all the stations are precisely alike, but suddenly at one or two stations the disturbance changes its character: for instance, on comparing Kew and St. Petersburg, we get perfect similarity followed by deflections of the needle opposite ways at the same instant, and in some such cases the maxima in opposite directions are reached at the same instant, showing that the opposite deflections are produced by the same cause, and that the immediate cause or medium of disturbance in such a case is not far off; probably it is some change of direction or intensity of the earth's magnetism arising from solar action upon it.

Generally, after an hour or two, these differences in the effects of the disturbance vanish, and the disturbances again become alike and simultaneous. In such cases of difference, if the curve-tracing of the horizontal or the vertical force be examined, it is generally found that, at the instant when these opposite movements begin there is an increase or a diminution in the horizontal force, and that the horizontal force continues to change as long as there is any difference in the character of the declination curves. It is clear, then, from these effects that the cause or causes of magnetic disturbances are in general far distant from the earth's surface, even when those disturbances are large; but that not unfrequently these causes act on magnetic matter nearer to the surface of the earth, and therefore at times between two places of observation, and nearer to one than another, thus producing opposite effects on the declination needle at those places; in such cases, the differences are probably due to changes in the earth's magnetic force. Now, if we imagine the masses of iron, nickel, and magnesium in the sun to retain even a slight degree of magnetic power in their gaseous state—and we know from the researches of Faraday that gases are some of them magnetic—we have a sufficient cause for all our terrestrial magnetic changes, for we know that these masses of metal are ever boiling up from the lower and hotter levels of the sun's atmosphere to the cooler upper regions, where they must again form clouds to throw out their light and heat, and to absorb the light and heat coming from the hotter lower regions; then they become condensed and are drawn again back towards the body of the sun, so forming those remarkable dark spaces or sun-spots by their downrush towards the lower levels.

In these vast changes, which we know from the science of energy must be taking place, but of the vastness of which we can have no conception, we have abundant cause for those magnetic changes which we observe at the same instant at distant points on the surface of the earth, and the same cause acting by induction on the magnetic matter within and on the earth may well produce changes in the magnitude or in the direction of its total magnetic force. These magnetic changes on the earth will influence the declination needles at different places, and will cause them to be deflected; the direction of the deflection must depend on the situation of the earth's magnetic axis or the direction of its motion with regard to the stations where the observations are made. Thus both directly and indirectly we may find in the Sun not only the cause of diurnal magnetic variations, but also the cause of these remarkable magnetic changes and disturbances over the surface of the Earth.

The following Reports and Papers were read:—

1. *Report of the Committee for the Measurement of the Lunar Disturbance of Gravity.*—See Reports, p. 25.

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2. *Report of the Committee upon the present state of our Knowledge of Spectrum Analysis. (Influence of Temperature and Pressure on the Spectra of Gases.)*—See Reports, p. 258.

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3. *On determining the Heights and Distances of Clouds by their reflexions in a low pool of water, and in a mercurial horizon. By* FRANCIS GALTON, *M.A., F.R.S.*

The calm surface of a sheet of water may be made to serve the purpose of a huge mirror in a gigantic vertical range-finder, whereby a sufficiently large parallax may be obtained for the effective measurement of clouds. The observation of the heights and thicknesses of the different strata of clouds, and of their rates of movement, is at the present time perhaps the most promising, as it is the least explored branch of meteorology. As there are comparatively few places in England where the two conditions are found of a pool of water well screened from wind, and of a station situated many feet in height above it, the author hopes by the publication of this memoir to induce some qualified persons who have access to favourable stations, to interest themselves in the subject, and to make observations.

The necessary angles may be obtained with a sextant and mercurial horizon, but it is convenient, for reasons shortly to be explained, to have in addition a tripod stand, with a bar of wood across its top to support the mercurial trough, and some simple instrument for the rapid and rough measurement of altitudes. I have used the little pocket instrument sold by Casella, of Holborn Bars, London, called a 'pocket alt-azimuth,' and have employed Captain George's mercurial horizon on account of its steadiness and ease in manipulation.

The observer has to determine:—

1. The difference of level in feet between the mercury and the pool of water (call it d).

2. The angle between the reflexions of a part of a cloud in the mercury and in the pool (call it p). This should be carefully measured.

3. The angle between the portion of the cloud and its reflexion in the *mercury* (call it $2\,a$). This may be roughly measured; its altitude a may most conveniently be taken at once by the pocket alt-azimuth or other instrument. The subjoined tables will then give the required result with great ease.

If p be not greater than 3°, and if n be the number of minutes of a degree in p, the error occasioned by writing $n \sin 1'$ for $\sin n'$, will never exceed six inches in a thousand feet, and may be disregarded. Other errors of similar unimportance, due to the eye not being close to the mercury, may also be ignored. Under these conditions, since log. sin. $1' = 6{\cdot}46373$, it can be easily shown that

$$\text{distance of cloud} = \frac{d}{n} \times 6875{\cdot}5 \cos (a + p).$$

$$\text{vertical height of cloud} = \text{distance} \times \sin a.$$

The following table has been calculated for these values when $\frac{d}{n} = 1$. To use it, multiply the tabular numbers by d (the difference in feet between the level of the mercury and that of the pool) and divide by n (the number of minutes of a degree in the angle between the reflexion in the mercury and that in the pool). The result will be the distance, or height, as required in feet.

TABLE for calculating distances and height of clouds by their reflexions from a mercurial horizon, and from a pool of water at a lower level.

a = Altitude of cloud, (being half the sextant angle between the cloud and its reflexion as seen in the *mercury*, not pool).

p = Angle between the reflexion of the cloud in the mercury and that in the pool.

d = Vertical height of mercury above pool.

n = Number of minutes of a degree in the angle p.

Then the distances and heights of clouds = tabular numbers $\times \frac{d}{n}$

$a+p$	Distance from Observer	Vertical Height of Cloud above Observer			
		$n=0$ (or $p=0°$)	$n=60$ (or $p=1°$)	$n=120$ (or $p=2°$)	$n=180$ (or $p=3°$)
10°	6771	1176	1059	942	825
15°	6641	1719	1607	1494	1381
20°	6461	2210	2103	1997	1889
25°	6231	2633	2534	2435	2334
30°	5954	2977	2886	2795	2703
35°	5632	3230	3149	3067	2985
40°	5267	3386	3314	3243	3170
45°	4862	3438	3377	3316	3253
50°	4419	3386	3335	3284	3232
55°	3944	3230	3198	3150	3108
60°	3438	2977	2947	2915	2883
65°	2906	2633	2612	2597	2566
70°	2352	2210	2195	2180	2165

The observation of the angle between the two reflexions is perfectly easy with a full-sized sextant, if the trough of mercury be so propped up that the reflexion from the pool can be viewed *underneath* the trough. For this purpose I use a tripod stand with a bar of rough wood, say 18 inches long, 3 wide, and 2 thick, secured horizontally across its top. I lay the mercurial horizon on one of its projecting ends and between a few studs that have been driven in to prevent its accidentally slipping off. The edge of the bar is bevelled, and its thickness is reduced at the place where the mercury trough is set. Then the observation is taken, just as any other sextant observation would be. The reflexion from the mercury falls upon the index-glass, and that from the pool is viewed directly through the object-glass below the trough and its supporting bar.

Unless the sextant be a full-sized one, this operation cannot be effected, because the index-glass will not stand high enough above the line of sight to catch the reflexion from the mercury. It will simply reflect the side of the trough.

If there be no tripod stand, and it becomes necessary to lay the trough on the ground, an observation can still be made, but in an inconvenient fashion. The sextant will have to be held topsy-turvy, that the brighter reflexion of the cloud from the mercury, and not the feebler one from the pool, should fall on its index-glass. The angle read will be negative; it will be what is commonly called an 'off' angle. A small sextant may be used in this method, because the rim of the trough is narrow that intervenes between the further edge of the mercury and the objects seen beyond and over it.

The most convenient method of measuring the rate of movement of clouds, after the height of the cloud plane has been once determined, is to watch the movements of a patch nearly overhead, and passing away from the zenith, as seen reflected in the mercury, and measuring its angle of depression (= its altitude) with some simple and suitable instrument, such as the pocket alt-azimuth already mentioned. Two measurements, a_1 and a_2 are taken, as well as the intervening time, t seconds, whence we obtain rate of movement = height of cloud × (cotan a_2 − cotan a_1) in t seconds.

When the water is almost wholly calm, I find that 2′ of error is the utmost that need be feared. If wholly calm 1′ would be ample to make allowance for in a set of three or four observations. Now suppose we wish that our determination shall never be more than, say, 10 per cent. in error, we can easily find from the tables what the minimum height of the station must be in any given case, to secure this result. In the first instance we should require a parallax of 10′ and in the second of 20′. This is obtained by an elevation of 10 or 20 feet as the case may be, when the height of the clouds in feet corresponds to the tabular numbers; that is, when it is between 2000 and 3000 feet. At 100 or 200 feet elevation, clouds of ten times that height could be observed with equal accuracy. Numerous

stations exist whence mountain tarns can be seen lying at a much lower level than this, and where even the highest cirrus could be measured with satisfactory precision.

Useful regular work might be done by a meteorologist whose station was at a height of even 50 feet above a pool, supposing it to be so well sheltered from the wind as to frequently afford perfectly good reflexions with, say, 1′ maximum error. Very shallow water is much stiller than deep water, as waves cannot be propagated over it; thus we may often see wonderfully good reflexions in road-side splashes and puddles, in the intervals between puffs of wind. The most stagnant air is in the middle of a high and broad plantation, where there is also plenty of dense underwood. Detached puddles of water in broad ruts would be a good equivalent for a pool. As regards the size of the pool, if we let fall a perpendicular k from the mercury trough to the level of the water, the utmost portion of the surface of the pool that can be used with effect extends between the distances of about $\frac{1}{2}k$ and $4k$ from the base of the perpendicular. The angles of depression would be then from 64° to 14° about, or say, a range of 50°. The usual limits would be from k to $3k$, or between 45° and 18°, being a range of 27°.

Improved Heliograph or Sun Signal. By TEMPEST ANDERSON, *M.D., B.Sc*

The author claims to have contrived a heliograph, or sun-telegraph, by which the rays of the sun can be directed on any given point with greater ease and certainty than by those at present in use.

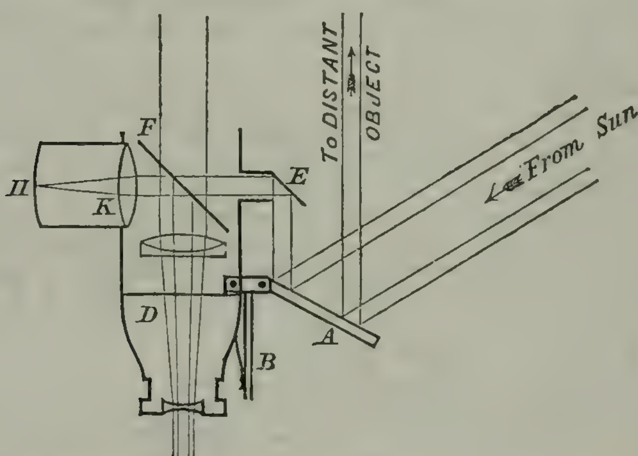
When the sun's rays are reflected at a small plane surface considered as a point, the reflected rays form a cone, whose vertex is at the reflector and whose vertical angle is equal to that subtended by the sun. Adding to the size of the mirror adds other cones of light, whose bounding rays are parallel with those proceeding from other points of the mirror, and only distant from them the same distance as the points on the mirror from which they are reflected. Hence increasing the size of the mirror only adds to the field to which the sun's rays are reflected a diameter equal to the diameter of the mirror, and this at any distance at which the sun-signal would be used is quite inappreciable. Adding to the size of the mirror adds to the number of rays sent to each point, and hence to the brightness of the visible flash, but not to the area over which it is visible.

By the author's plan, an ordinary field-glass is used to find the position of the object to be signalled to, and to it is attached, in the position of the ordinary sun-shade, a small and light apparatus, so arranged that when the mirror is turned to direct the cone of rays to any object within the field of view of the glass, an image of the sun appears in the field, at the same time as the image of the distant object, and magnified to the same degree, and the part of the field covered by this image is exactly that part to which the rays are reflected, and at which some part of the sun's disc is visible in the mirror.

A perfectly plane silvered mirror, A, takes up the rays of the sun, and when in proper position reflects them parallel with the axis of D, which is one barrel of an ordinary field-glass. The greater part of the light passes away to the distant object, but some is taken up by the small silvered mirror E, which is placed at an angle of 45° to the axis of D, and reflected at a right angle through the unsilvered plane mirror, F, and the convex lens, K, by which it is brought to a focus on the white screen, H, which is placed in the principal focus of K. The rays from this image diverge in all directions, and some are taken up by the lens K and restored to parallelism; some of these are reflected by the unsilvered mirror, F, down to the field-glass, D, and if this is focussed for parallel rays, as is the case in looking at distant objects, an image of the sun is seen projected on the same field of view as that of the distant object. As the mirrors E and F are adjusted strictly parallel, the rays proceeding from F into the field-glass are parallel and in the opposite direction to those going from the mirror A to E, which form part of the same pencil as those going to the distant object. Hence the image of the sun seen in the field exactly covers the object to which the sun-flash is visible, and in whatever

direction the mirror A is moved so as to alter the direction in which rays are reflected to the distant object, and the angle at which part impinge on E and are reflected through the lens K, the image visible in the glass moves in the same direction. Several attempts to produce this result were made by the use of mirrors and prisms, before the lens K was introduced, but they all failed. It was easy to make the image of the sun cover the object when the two occupied the centre of the field of view, but directly the mirror was inclined so as to direct the rays not strictly parallel to the axis of the field-glass, the apparent image diverged generally in the same direction along one co-ordinate, and in the opposite along one at right angles to it, so that nowhere, but in one line across the field, did the image lie in the desired position. The mirrors E and F are adjusted parallel once for all, by noticing the position on a screen of the small spot of light reflected from the front of F as the light passes from E to K. The mirrors are moved by the adjusting screws till this spot has, to the bright reflection from the mirror A, the same relative position that the centre of mirror F has to the mirror A.

In actual use the field-glass is first fixed in position pointing to the object, either by holding steadily in the hand, or better by a clamp attached, by which it can be screwed into a tree or post, or fixed in the muzzle of a rifle. The instrument is turned on the barrel of the glass till the sun is in the plane passing through the two axes of the instrument, and the mirror A is turned till the bright image of



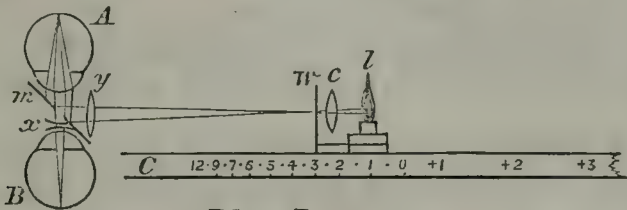
the sun is seen on the screen H, through a hole left for the purpose in the side of the tube. On looking through the glass the sun's image is seen, and by then slightly rotating the instrument or moving the mirror, is made to cover the object. The mirror A is connected not directly to the body of the instrument, but to a lever B, on which it works stiffly, so as to retain any position in which it is placed. Lever B works easily and has a limited range of motion, to one end of which it is pressed by a spring; slight pressure with the finger moves it and its attached mirror, so as to throw the light on and off the object in a succession of long and short flashes by which letters and words may be indicated.

Mr. F. Galton said that the steadiness of aim required would be so great that it would be impossible with the instrument exhibited to give signals with precision without using a stand. He proposed that a convex or concave lens, of about 30 feet focus, should be attached near E, in the path of the rays from the mirror to the distant object, so as to disperse them over a field about three times the apparent diameter of the sun. This would render free-handed signalling practicable, though it would diminish the brightness of the flashes, and the instrument without the lens could be used to attract attention.

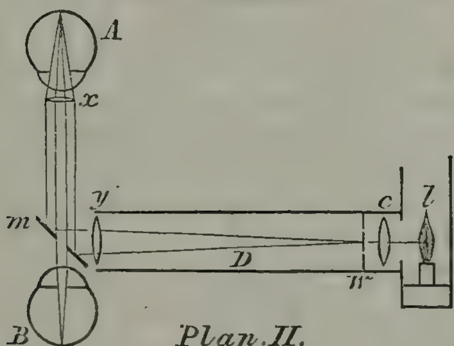
The above instrument answers well for all positions of the sun except when very low behind the observer's back. For this case another mirror is provided by which the light is reflected on to the mirror A.

5. *Improved Apparatus for the Objective Estimation of Astigmatism.* *By* TEMPEST ANDERSON, *M.D.*, *B.Sc.*

Astigmatism has been defined as that condition of the eye in which refraction is unequal in the different meridians. In order to obtain suitable spectacles for correcting this defect, it is necessary to know accurately the focal adjustment of the meridians of maximum and minimum curvature, whence the focal lengths of glasses, generally either cylindrical or cylindrical on one side and spherical on the other, are readily calculated. Many plans have been adopted for determining this; some subjective, depending on observations made by the eye itself, and generally using a point of light or a series of radiating lines as an object. From their appearances when viewed at different distances, and with lenses of different powers, the focal adjustment of the different meridians is at last obtained.



Plan I.



Plan II.

References to both figures :—

A. Observed eye.
B. Observing eye.
m. Mirror.
l. Lamp.
c. Condensing lens.
w. Wire screen, seen edgeways.
y. Principal lens.
x. Correcting lens.
Plan I.—*C.* Graduated bar.
Plan II.—*D.* Tube.

The advantage of this group of methods is their theoretical delicacy, as they work by judging of the perfection of certain images refracted on the retina in a manner not very dissimilar to that in which they are usually formed; the practical disadvantage, that accurate observations are required from one who has never been accustomed to make them. Hence objective methods have been introduced. Their advantages are, substituting trained for untrained observation. Their disadvantages—(1) The vessels of the retina and the optic nerves, which are mostly employed as objects, are seldom in exactly the position desirable for estimating the refraction in different meridians, and are often at a different distance from the optical system of the eye from that at which the sensitive layer of the retina lies.

(2) They mostly require the optical defects, if any, and the accommodation of the observing eye to be taken into account and allowed for, thus introducing risk of error.

In the author's two instruments, an image of a suitable object thrown on the retina of the observed eye, is used as an object by the observer, with the following advantages:—

(1) The patient's sensations may be entirely disregarded, or only used as confirmatory.

(2) The image used is necessarily at the retina, and not before or behind it.

(3) The accommodation, or any defects in the refraction of the observer's eye, does not enter into the result, as the only function of this eye is to observe the formation of the image on the retina.

In the first plan a lamp *l* is provided with a condensing lens *c*, and a series of radiating wires *w* (supposed to be seen edgeways in the figure), thus giving a bright field with black lines on it.

The whole slides on a graduated bar, *C*, at the other end of which is a convex lens, *y* [4 and 10 dioptrics are the most convenient powers, *i.e.* 10 and 4 inch focus]. Close to the lens, and at an angle of 45° to its axis, is a plane mirror (*m*), which reflects the rays at right angles to their former path. The instrument is to be held so that this pencil of rays enters the observed eye, and when the wire screen is at the proper distance, an image of it is formed on the retina. The mirror has the centre left unsilvered, as in an ordinary ophthalmoscope, and has a disc of correcting lenses behind it, to render the retina, and the image on it, visible by the direct method. The observed eye should have its accommodation relaxed by atropine.

The bar is so divided that when an image of the whole or part of the screen is sharp on the retina, the graduation expresses the refractive error of the corresponding meridian. Hence, if the image of the whole screen is seen to be equally sharp, the eye is known to be not astigmatic, and the graduation gives the number of dioptrics by which it is myopic or hypermetropic. If the lines be not all equally sharp, then the most distant point at which a distinct image of any of the wires is formed on the retina gives the refractive error of the meridian of minimum refraction expressed in dioptrics, and the point at which the line at right angles to this is best defined, gives that of the meridian of maximum refraction. The least of these gives the spherical element of the correcting lens required for distant objects, and the difference between the two gives that of the cylindrical part. The meridian of maximum refraction is that in which the line is visible when the wires are at the greatest distance.

In the second plan the lamp, *l*, condensing lens, *c*, and wire screen, *w*, are similar, and only differ in size, the front lens, *y*, and mirror, *m*, are also similar, but the lamp and wires are permanently fixed by a tube, so that the wires are accurately in the principal focus of the front lens, *y*. By this means the rays from the wires (or rather from the interval between them), after refraction through the lens and reflection by the mirror, are parallel. If received by an eye which is emmetropic, and with its accommodation relaxed, an image of the wires is formed on the retina. The light radiating from this image passes out through the optical system of the eye; is rendered parallel and able to form an accurate image on the retina of an emmetropic eye observing through the hole in the mirror.

If the observed eye be not emmetropic, it is only necessary to introduce lenses of different powers close in front of it, so as to correct the rays both entering and leaving the eye. If the refraction be the same in all meridians, the image of all the wires is sharp with the same lens, and this lens is the one required to correct the ametropia. If any astigmatism exists, different lenses are required for rendering the images of the different wires sharp.

The strongest and weakest of these are the measures of the errors of refraction of the two principal meridians, and the difference of their numbers of dioptrics gives the cylindrical element of the correcting glass required.

In this form of apparatus a disc of correcting lenses behind the mirror is not required, as the single correcting lens near the observed eye corrects the rays both entering and leaving the eye.

For rapidly finding the proper lens a disc of lenses is used, each a centimètre in diameter, and with intervals of one dioptric; a smaller disc is attached containing the quarter dioptrics, so that by their combination intervals of one quarter of a dioptric can be read—a degree of accuracy greater than the estimation is generally susceptible of.

The proper lens being calculated, its spherical and cylindrical elements are combined and put together before the eye. If it be the correct one, all the lines are seen sharp at the same time. If not, further examination is made.

The principal advantage of the first plan is that the adjustment, being made by the motion of the wire screen, is continuous, and correcting lenses are not required for measuring the refraction, but only for rendering the retinal image visible; its disadvantage that, as the rays are not parallel as they pass from the front lens, past the mirror to the eye, it is necessary for the apparatus to be very near, and at a determinate distance from the observed eye, otherwise the readings of the scale are vitiated. This, however, is not a serious objection.

In the second plan the rays in the corresponding position are parallel, and the instrument can be held at any convenient distance, say 1 or 2 feet from the observed eye, and the observer can get a view of the cornea at the same time as he views the image, so that he can estimate the refraction at different points of the the cornea.

It is hoped that this may eventually lead to the determination of the refraction at different parts of conical cornea and other eyes with irregular astigmatism, and the application of suitable lenses to them.

Since writing the above, I find mention of an instrument by Coccius Stimmel, with an optical arrangement on the same plan as my second, but I have not heard of its being in use in this country. The makers are T. Cooke & Sons, York.

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6. *On the Length of the Sun-spot Period.*[1] *By* HENRY MUIRHEAD, *M.D.*

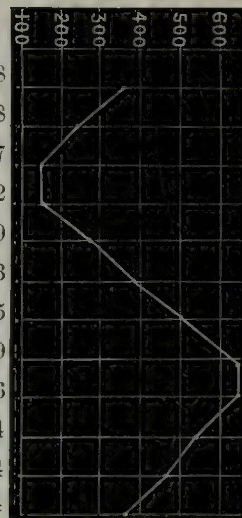
It is well known to all who take an interest in the phenomena of sun-spots that men of science are far from being agreed as to the length of the period intervening between one maximum epoch and another. I should think, however, that those who wish to prove that our rain, our storms, terrestrial magnetism, harvests of grain and vintage, with commercial crises, &c., depend a good deal on how the face of the sun is covered, should first of all make sure of the real length of the sun-spot period. To help towards its fixation I beg to bring under the notice of the Section the following table arranged from Wolf's *latest corrected* relative sun-spot numbers, from 1770 till 1877, with accompanying tracing. The numbers are arranged to correspond with Jupiter's period of 11·863 years. Each vertical column (save one) commences with the year in which Jupiter's heliocentric longitude is $263\frac{3}{4}°$. The last column is the summation. The dates of the cycles were chosen on the supposition that much of the sun's radiance arises from matter impinging on his atmosphere—just as so-called star-showers light up ours—and that when Jupiter is in or near the front of the sun's march in space (*i.e.* hel. long. $263\frac{3}{4}°$) he intercepts a good deal of the meteoric aggregations which would otherwise impinge against the sun's envelopes, giving rise to sun-spots till sublimated. We know that comets whose aphelia are about as distant as Jupiter's orbit have periods of about five years; so meteoric matter may be supposed to take about two and a half years to come from Jupiter to the sun. Now please observe that the average minimum sun-spot epoch occurs about two and a half years after Jupiter is at R.A. $263\frac{3}{4}°$, and the maximum about six years after the minimum, that is, when we might expect Jupiter's intercepting influence to be least. But leaving out of account this hypothesis, the fact remains—as the table and tracings[2] show—that the sun-spot period is not 10 years, nor 11, nor 11·1, but seemingly 11·863, corresponding with Jupiter's period. It is to this conclusion that I wish to call the attention of meteorologists and others, who wish to show a correspondence between their various periodicities and those of sun-spots. In 1875 I brought this before the Philosophical Society of Glasgow, and also produced evidence to

[1] Will be published *in extenso* in the *Proceedings of the Philosophical Society of Glasgow*, vol. xii. 1880–81.

[2] A diagram extending *horizontally* was also shown.

show Jupiter's influence on terrestrial magnetism. I then further said: 'On my hypothesis we may expect the decrement of the sun-spots to go on till some two years after Jupiter's passing nearest the sun's future path in April, 1877.'—'Proc. Phil. Soc. Glasg.' vol. x. p. 55.

	July 19, 1770.	May 30, 1782.	April 29, 1794.	Feb. 17, 1806.	3 days before 1818.	Nov. 10, 1829.	Sept. 19, 1841.	July 31, 1853.	June 10, 1865.	
1 .	79	33	34	25	34	54	30	38	31	358
2 .	43	22	22	15	22	59	20	19	16	238
3 .	49	5	15	7	9	39	9	7	7	147
4 .	40	21	8	3	4	22	13	4	37	152
5 .	48	87	4	0	3	8	33	22	74	279
6 .	28	105	10	1	1	11	47	51	139	393
7 .	35	108	18	5	7	46	79	96	111	505
8 .	63	111	39	14	17	97	100	96	102	639
9 .	95	84	58	20	29	111	96	77	66	636
10 .	90	53	65	35	40	83	64	59	45	534
11 .	73	47	75	45	53	68	62	44	17	484
12 .	68	40	50	44		52	52	47	11	364
				Dec. 29, 1817.						



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7. *Sur la Calculation des Phénomènes périodiques. Par le* Professeur RAGONA.

L'auteur fait connaître un perfectionnement qu'il a introduit dans l'usage de la formule de Bessel, c'est-à-dire de la formule des phénomènes périodiques. Il consiste à établir le *schema* des valeurs calculées par la formule, jusqu'aux secondes différences, et à trouver les instants dans lesquels les secondes différences changent de signe. La demi-somme de deux de ces instants successives, donne un maximum en passant d'un changement de + *à* − à'un changement de − *à* +. Elle donne un minimum en passant d'un changement de − *à* +, à un changement de + *à* −.

Si on fait usage d'un nombre d'observations pas suffisamment étendues, ou d'observations exécutées dans une époque de disturbations atmosphériques, la formule donne *toujours* des résultats qui sont plus proches à l'expression de la véritable loi de phénomène, si les maximum et les minimum sont déduits par la méthode que l'auteur a proposé, et qu'il appelle méthode des *inflexions.*

L'auteur a plusieurs fois traité, *à priori* et *à posteriori,* de l'utilité de la méthode des inflexions. Une de ces démonstrations est relative à la vitesse du vent. La loi annuelle de cette vitesse est exactement connue à Modène. Dans le cours de l'année se développent trois maximum et trois minimum, qui correspondent inversement au trois maximum et trois minimum que manifeste la pression barométrique dans la période annuelle. En faisant usage d'une série de 12 années de bons observations l'auteur a établi deux formules, la première sur 6 années et la seconde sur tous les 12 années. La dernière donne exactement les trois *max.* et trois *min.* annuels, tandis que la première donne, et d'une manière très-imparfaite, seulement deux *max.* et deux *min.* Mais si dans la première on fait usage de la méthode des *inflexions,* on obtient d'elle avec beaucoup d'exactitude la véritable distribution des *max.* et des *min.* de la vitesse du vent.

L'auteur expose à la section un autre exemple de l'utilité de la méthode qu'il a proposé.

Le prof. Mascart, a dernièrement publié à Paris les résultats d'une série d'observations sur l'électricité atmosphérique. La loi moyenne diurne de l'électricité atmosphérique est bien connue à Modène. Il s'agit de deux *max.* et deux *min.* qui correspondent à peu près aux heures critiques barométriques. M. Mascart dit que ses observations ont été exécutées dans une époque de fortes perturbations atmosphériques. Calculant les observations de M. Mascart par la formule de Bessel, l'auteur a obtenu seulement un *max.* et un *min.*, mais en faisant usage de la méthode des inflexions, a obtenu exactement le deux *max.* et les deux *min.* diurnes de l'électricité atmosphérique.

L'auteur donne notice d'une série d'observations qu'il a exécutées sur la période diurne de l'électricité atmosphérique. Il a obtenu les deux *max.* et les deux *min.* presque en coïncidence avec les valeurs déduits des observations de M. Mascart par la méthode des *inflexions,* ce qui est remarquable à cause de la différence des lieux et des époques. Il fait noter qu'il s'agit toujours de la marche diurne de l'électricité positive, parce que l'auteur a, comme M. Mascart, eliminé tous les jours d'electricite négative.

L'auteur fait connaître aussi un résultat digne d'attention de ses observations sur la période diurne de l'électricité dynamique, c'est-à-dire des courants qui montent ou descendent dans les hautes édifices. Sur la tour de l'Observatoire de Modène il a placé un excellent galvanomètre, dont les deux poles étaient en communication un avec le terrain et l'autre avec le toit de la tour. En considérant seulement l'intensité du courant ascendant, il a trouvé que son période diurne est exactement inverse de celui de l'électricité atmosphérique ; c'est-à-dire que les *max.* d'intensité du courant ascendant correspondent aux *min.* d'intensité de l'électricité libre positive de l'atmosphère, et inversement.

8. *On the Laws of the Change of Speed and Direction of the Wind.*
By Professor Ragona.

FRIDAY, AUGUST 27.

The following Reports and Papers were read :—

1. *Report of the Committee on Underground Temperature.*
See Reports, p. 26.

2. *Report of the Committee appointed to devise and construct an improved form of High Insulation Key for Electrometer Work.*
See Reports, p. 29.

3. *Comparison of Curves of the Declination Magnetographs at Kew, Stonyhurst, Coimbra, Lisbon, Vienna, and St. Petersburg.* *By* Professor W. Grylls Adams, *M.A.*, *F.R.S.*—See Reports, p. 201.

4. *On the best form of Magnet for Magneto-electric Machines.*
By W. Ladd, *F.R.A.S.*

At the British Association Meeting at Dundee, in 1867, I made some remarks upon different forms of magnet, and exhibited diagrams, showing by the 'lines

of force'—naturally arranged—the great superiority of the circular magnet, where an armature is to be employed.

Since that time some thousands of that form of magnet have been made for medical, mining, and other purposes.

Some months ago, when in conversation with M. Breguet of Paris, I showed him these same diagrams, and he was very much impressed with their importance. He has since then constructed a machine, using the Gramme armature; and with a smaller quantity of steel in the magnets he has made a far more powerful machine than hitherto constructed with either the Jamin or the ordinary horse-shoe form. It is also more symmetrical in appearance and occupies less space.

With this machine I can heat to incandescence 19 inches of platinum wire by four turns of the handle; while to heat 14 inches of the same sized wire by a machine having a Jamin magnet took ten turns of the handle.

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5. *An Account of some Experiments in Photo-electricity.* *By* G. M. Minchin, *M.A.*

The two objects aimed at primarily in photo-electricity are—

(*a*) the production, at a distance, of effects due, in the first instance, to the photographic action of light;

(*b*) the continuous daily registration of the intensity of sunlight of any selected wave-length.

The first of these is the problem of constructing what the author has called the *Telephotograph,* and some of the fundamental conditions of success have been attained.

The second problem will, in all probability, soon attain a satisfactory solution, much progress having been already made towards it.

The author investigated, in the first instance, the photo-electric currents produced by the action of light on silver plates, coated with the ordinary emulsions of silver salts in use among photographers—viz., the chloride, bromide, and iodide of silver.

In a cell containing tap water (or slightly acidulated water, or distilled water with a few grains of common salt), if a chloride plate is immersed in presence of an uncoated plate, the current runs from the latter to the former in the cell.

The same is the direction of the current when the chloride is replaced by a bromide plate.

But if the sensitised plate is an iodide plate (the conducting liquid being distilled water with a few grains of iodide of potassium), the direction of the current is reversed.

In carrying out an idea about phosphorescence as a photo-electric source, it appeared to be of importance to study sulphide of silver. If any emulsion of this salt is made with collodion, and a silver-plate sensitised with it be immersed, as above, in a glass cell, the direction of the current given by magnesium light (or sunlight), agrees with that of the iodide plate; and by passing the light incident on the plate through coloured glasses, it will be found that the red and the blue rays give strong results in the same direction, while the green light gives a comparatively trifling action. For this salt there is therefore a point of minimum sensibility in the middle of the spectrum. A silver plate coated with nitrate of silver (shaken up in a test-tube with thin photographic gelatine), gave with blue rays a strong current in the iodide and sulphide direction; and with red rays a very small result in the opposite direction, though whether this latter result is due to the action of the red rays on the emulsion or on the plate itself is not certain.

It was found in several of these experiments that the observation of Grove to the effect that light sets up a current in the direction of some previously existing current, being incapable of setting up one of its own, was not confirmed. The experiments of Grove which gave rise to this statement are referred to. From

even a purely logical consideration we might conclude that his statement cannot be accepted.

The photographic effect of a current which is passed through a sensitised plate is a point of fundamental importance. By placing two plates, each coated with Liverpool Emulsion, in a cell containing distilled water and a few grains of bromide of potassium, and putting this cell into the circuit of a bichromate cell for a few seconds, it will be found that—

(*a*) the plate connected with the carbon pole is, without the employment of a developer, visibly blackened in its immersed portion;

(*b*) no visible change comes on the other plate; but when this plate is developed by pyrogallic acid, its immersed portion also becomes dark.

This fundamental result was also obtained (though in a less marked degree) by the action of a photo-electric cell, instead of the bichromate cell. To produce the effect with greater ease in this case, expose the two bromide plates to gas-light for about ten seconds before immersion. The localisation of the effect on the plate through which the current passed was further shown by placing several silver strips on the same plate of glass, coating all of them with a layer of Liverpool Emulsion, and throwing some of them out of the circuit of the current. Only those in circuit exhibit the photographic effect. Assuming that fluorescence ought to operate a change of luminous energy into that of an electric current, the author next replaced the silver salts by fluorescent substances. Eosine gave the best results, but it is very easily soluble and it leaves the plate rapidly. A very permanent eosine plate was obtained by making a mixture of eosine solution and thin gelatine, pouring this over the plate, and then pouring a layer of collodion over it. This was exceedingly sensitive to even dull sunlight, and when connected with a galvanometer, indicated the faintest change in the light which it received. As a perfect photometer it has a drawback. When the light is suddenly shut off, the spot on the scale does not immediately return to zero. It was found that this irregularity was due (partly at least) to the action of light on collodion, and this latter was specially examined. A less sensitive, but more regular, plate was made by mixing eosine with thin gelatine and rendering the layer insoluble by immersion in alum solution.

Naphthalene red gives also very good results, and comes near satisfying the requirements of a perfect photometer for continuous registration. Strong light gives opposite results by the action of red and blue rays. Iodine-green—an aniline dye—gives very strong currents, in the direction opposed to that of the current given by an emulsion of iodide of silver—a result for which a theoretical reason may be given.

The E.M.F. of this cell for strong but oblique sunlight was in one experiment found to rise so high as $\frac{1}{20}$th of a Daniell.

To prevent the solubility of several of the substances employed, mordants—such as chloride of aluminium and borax—were employed; but though the layers on the plates were rendered insoluble, their sensitiveness to light was almost destroyed.

A very curious case of inverse currents presented itself. Two clean silver plates were immersed in a glass cell containing a solution of eosine. When light fell on one plate a current was suddenly set up in the direction opposite that given by a plate coated with eosine and immersed in water. This was a small jerky current, lasting for a second or so, and it was immediately succeeded by a large current in the opposite direction which varied with the light intensity. When the light was suddenly shut off a further jerk in the latter direction took place, and then the spot moved towards its zero position. The two plates having been then left immersed in the cell for a fortnight, were again used in the same manner and it was found that the jerk had enormously increased; but, although the light was kept up, the spot steadily came back and moved in its normal direction beyond its zero position—far beyond it if the light was strong, such as that of a candle at a distance of three or four inches. These contrary currents appear to the author to point to a mechanical action of light on the eosine in solution, as distinct from the chemical action set up between the eosine layer and the silver plate in contact

with it. The immersed plates become each coated with a layer of a darkish appearance (eoside of silver ?), and this layer will give a current in the same direction as that given by a silver plate coated in the old way with any emulsion of eosine.

Platinum plates always give in these experiments much smaller results than silver plates; but this fact may be due to the circumstance that, with the substances employed, silver may be a better vehicle for the transference of the energy than platinum—apart from the consideration of chemical action.

Several other substances, such as fluorescine, fuchsine, sulphate of quinine, &c. were used, the results being less marked.

Phosphorescence was studied by coating a platinum plate with a mixture of gelatine and sulphide of calcium, and currents were produced by the action of magnesium light.

Experiments of the class last referred to are in progress.

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6. *Electric Convection-Currents. By* SILVANUS P. THOMPSON, *D.Sc., B.A., Professor of Experimental Physics in University College, Bristol.*

In a paper 'On the Action of Magnets on Mobile Conductors of Currents,' read before this Section a year ago, the author discussed a number of cases of the flow of electricity across a magnetic field. These included cases of true metallic conduction, of electrolytic conduction, and of those less-understood kinds of conductivity which occur in the voltaic arc, in the discharges in rarefied media, and in the luminous brush-charge at a point. For the case of convection of electricity, either automatically, by self-repulsion between electrified particles of a gas, or mechanically, the electro-magnetic effect is identical with that of a current in which the same quantity of electricity would be transferred in the same time; the 'rate of convection' $\frac{\delta Q}{\delta t}$ being in these cases the equivalent of 'the strength of the current.'

Maxwell's theory (vol. ii. art. 768) concerning the virtual identity of a current sheet and of an electrified sheet moving in its own plane with a velocity equal to 'v,' may be extended to the case of linear currents. The identity may be generalised to all cases of convection-currents.

Last year the author predicted that the brush discharge at a point would experience a spiral twist when taking place in the magnetic field. He has since found this to be experimentally the case.

The author also pointed out the similarity between the magnetic distortion found by Reitlinger and Wächter in electric ring-figures, and that found by himself to be produced by the presence of a magnet on Nobili's figures. He also referred to Maxwell's theory as explaining some of the phenomena observed in the exhausted tubes of Mr. Crookes, in which the discharges from the negative electrode behave like convection-currents having a velocity less than the velocity of light.

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7. *On a peculiar behaviour of Copper. By* WILLIAM HENRY PREECE.

From some experiments made in Dr. Warren De La Rue's laboratory it appeared that in some cases copper wires did not acquire their normal resistance until currents of electricity had passed through them. In several instances the resistance of virgin copper was far higher than it was after electricity had passed through.

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8. *On the proper form of Lightning Conductors. By* WILLIAM HENRY PREECE.

The question of the relative value of surface and sectional area in lightning-conductors never having been satisfactorily solved experimentally, the author, with the aid of Dr. De La Rue's gigantic battery, endeavoured to do so. He obtained wire tubes and ribbons of copper and lead of similar lengths and weight, and

passed very powerful charges of electricity through them, observing their thermic effects upon platinum and silver wires. It was found that change of form produced no difference whatever in the character of the discharge, and it was proved that the discharges of electricity of high potential obey the laws of Ohm. No more efficient lightning conductor can be devised than a cylindrical rod or a wire rope.

9. *On the necessity for a regular Inspection of Lightning Conductors.* *By* RICHARD ANDERSON, *F.C.S.*, *A.Inst.C.E.*

The author referred to a paper by M. W. de Fonvielle, 'On the advantage of keeping records of Physical Phenomena connected with Thunderstorms,' read before this Association in 1872. M. de Fonvielle recommended to the attention of the members the steps which had been taken by the French Government for obtaining information regarding thunderstorms, and suggested that the Association should institute some organisation for the collection of such data; arguing that it would be of much value to science, as well as to the public. Nothing, however, has been done by the Association since 1872; and the author not only confirmed the conclusions at which M. de Fonvielle arrived as to the desirability of collecting such data, but was of opinion that the organisation should go further, and arrange for a regular inspection of all public buildings which had lightning-conductors applied.

The necessity for this he demonstrated by adducing a number of striking cases where damage, more or less severe, had occurred to buildings, even though having lightning conductors attached to them. The cases now cited, he explained, were supplementary to those communicated in his paper on a similar subject to the Association in 1878. A few of the cases were as follows:—

In October, 1878, an elevated building situated at the back of Victoria Station, occupied as a furniture repository, was struck by lightning and sustained damage, although furnished with a $\frac{3}{4}$-inch by $\frac{1}{8}$-inch copper-band lightning conductor and a tube of $\frac{5}{8}$-inch diameter rising above the iron crestings on tower. The lightning shattered the cresting and bent the point of the lightning-rod, besides doing other damage to the building. On testing, the author found the resistance very great, and on opening out the earth-terminal found it embedded in concrete.

In June last St. Mark's Church, Skelton, was struck by lightning, when the air-terminal of a $\frac{5}{8}$-inch diameter copper-rope conductor was slightly bent. On testing, the author found the resistance great, and on opening the ground, the conductor was found to be carried from the building about 14 feet and buried among brick and stone rubbish. The conductivity of the copper was 52·50 instead of 92 to 94 per cent.

On June 26 last lightning struck All Saints' Church, Lambeth, doing considerable damage, although there was a $\frac{5}{8}$-inch diameter copper-rope conductor on the west gable, with a copper tube rising 18 inches above. A stone cross about 50 feet from the conductor was thrown down, injuring the roof of the north aisle. On testing the conductor, the author found that it had no 'earth' whatever, the rope being simply placed in 2 inches of loose rubbish. The copper was of very inferior quality; conductivity being 32·10 per cent., or about double that of iron.

The author quoted also a few cases from his recent work on 'Lightning Conductors, their History, &c.':—

In August, 1878, the Powder Magazine at Victoria Colliery, Burntcliffe, Yorkshire, was struck by lightning, though furnished with a conductor 13 feet above the building and terminating in 13 feet of clayey soil. The building was blown to pieces. On testing the conductivity of the copper it was found to be 39·2, instead of 92 to 94 per cent. The conductor was insulated from the building and from a large iron door, which it ought not to have been.

The author concludes from this evidence that it is not sufficient merely that rods of copper should be attached to a building, but it is necessary that after being fixed they should be regularly inspected, to see if they are in good order, so as to be really efficacious.

10. *Note on the Theory of the Induction Balance. By* LORD RAYLEIGH, *F.R.S., Professor of Experimental Physics in the University of Cambridge.*

This subject has been treated by Dr. Lodge in the 'Phil. Mag.' for February, 1880, who has arrived at several interesting results. The investigation may be considerably simplified by taking the case of pure tones, as is usual in acoustics. We may also suppose, for distinctness of conception, that the current in the primary circuit (x_1) is sensibly unaffected by the reaction of derived currents, though our results will be independent of this hypothesis.

If $x_1\, x_2 \ldots$ be the currents, $R_1\, R_2 \ldots$ the resistances, $M_{11}\, M_{22}\, M_{12} \ldots$ the coefficients of self-induction, and of mutual induction, the equations for three circuits are

$$M_{22}\frac{dx_2}{dt} + M_{23}\frac{dx_3}{dt} + R_2 x_2 = -M_{12}\frac{dx_1}{dt}$$

$$M_{23}\frac{dx_2}{dt} + M_{33}\frac{dx_3}{dt} + R_3 x_3 = -M_{13}\frac{dx_1}{dt}$$

We now assume that $x_1\, x_2 \ldots$ are proportional to e^{int}, where $n \div 2\pi$ is the frequency of vibration. Thus:—

$$in\,(M_{22}\,x_2 + M_{23}\,x_3) + R_2\,x_2 = -\,in\,M_{12}\,x_1$$
$$in\,(M_{23}\,x_2 + M_{33}\,x_3) + R_3\,x_3 = -\,in\,M_{13}\,x_1$$

whence by elimination of x_3

$$x_2\left\{ in\,M_{22} + R_2 + \frac{M^2_{23}\,n^2}{in\,M_{33} + R_3} \right\} = -\,in\,M_{12}\,x_1 - \frac{n^2\,M_{13}\,M_{23}\,x_1}{in\,M_{33} + R_3}$$

From this it appears that a want of balance depending on M_{12} cannot compensate for the action of the tertiary circuit, so as to produce silence in the secondary (telephone) circuit, unless R_3 be negligible in comparison with $n\,M_{33}$, that is unless the time-constant of the tertiary circuit be very great in comparison with the period of the vibration. Otherwise the effects are of different phases, and therefore incapable of balancing.

We will now introduce a fourth circuit, and suppose that the primary and secondary circuits are accurately conjugate, so that $M_{12}=0$, and also that the mutual induction between the third and fourth circuits (M_{34}) may be neglected. Thus

$$in\,(M_{22}\,x_2 + M_{23}\,x_3 + M_{24}\,x_4) + R_2\,x_2 = 0$$
$$in\,(M_{32}\,x_2 + M_{33}\,x_3) + R_3\,x_3 = -\,in\,M_{13}\,x_1$$
$$in\,(M_{42}\,x_2 + M_{44}\,x_4) + R_4\,x_4 = -\,in\,M_{14}\,x_1$$

whence

$$x_2\left(in\;M_{22} + R_2 + \frac{n^2\,M^2_{23}}{in\,M_{33} + R_3} + \frac{n^2\,M^2_{24}}{in\,M_{44} + R_4}\right)$$
$$= -\,n^2\;x_1\left(\frac{M_{13}\,M_{23}}{in\,M_{33} + R_3} + \frac{M_{14}\,M_{24}}{in\,M_{44} + R_4}\right)$$

Two conditions must be satisfied to secure a balance, since both the phases and the intensities of the separate effects must be the same. The first condition requires that the time-constants of the third and fourth circuits be equal, unless both be either very great or very small in comparison with the period. If this condition be satisfied, a balance may be obtained by shifting the circuits so as to bring $M_{13}\,M_{23}$ into equality with $M_{14}\,M_{24}$.

For a coil of mean radius a, and radius of section equal to $a \div 3{\cdot}22$, the coefficient of self-induction (L) is * $12\,\pi\,n^2\,a$, n being the number of turns. Also, if r be the specific resistance,

$$R = \frac{2\,\pi\,na}{\dfrac{\pi\,a^2}{n\,(3{\cdot}22)^2}}\,r = \frac{2\,(3{\cdot}22)^2\,n^2\,r}{a}$$

* Maxwell, *Electricity and Magnetism*, § 707.

For copper $r = 1640$, so that

$$\tau = \frac{L}{R} = \frac{a^2}{1810} \text{ on the } C.\,G.\,S. \text{ system.}$$

In the case of a *shilling* the time-constant can scarcely be so high as a ten-thousandth of a second, but periods smaller than this may be concerned when a microphone clock is employed.

For similar discs or coins the time-constant varies as $a^2 r^{-1}$, a being the linear dimension and r the specific resistance. Equal coins cannot in general be balanced if the specific resistances are different. To obtain a balance, a^2 should vary as r. In this case

$$\frac{M_{13} M_{23}}{in\, M_{33} + R} \text{ varies as } \frac{a^2}{r\, a^{-1}} \text{ varies as } \frac{a^3}{r} \text{ varies as } a,$$

on the supposition that the positions of the coins relatively to the primary and secondary coils are the same.

A perfect balance is not to be expected in general without two adjustments, though in some cases a fair approximation may be obtained with the sliding wedge employed by Hughes.

If the condition of equality of time-constants be satisfied, the remaining condition is independent of the value of n, so that a perfect balance for one pitch secures a perfect balance for all pitches. From this it follows that the results are not limited to simple tones, and that the two conditions are sufficient to secure a balance in all cases. It should be remembered, however, that this indifference to pitch does not apply to approximate balances, which may be satisfactory with one sound, but quite inadequate when another is substituted.

SATURDAY, AUGUST 28.

The following Reports and Papers were read:—

1. *Report of the Committee on Mathematical Tables.* See Reports, p. 30.

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2. *Report of the Committee appointed to calculate Tables of the Fundamental Invariants of Algebraic Forms.*—See Reports, p. 38.

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3. *Report on the present state of knowledge of the application of Quadratures and Interpolations to Actual Data. By* C. W. MERRIFIELD, *F.R.S.* See Reports, p. 321.

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4. *On Maximum and Minimum Energy in Vortex Motion. By* Professor Sir WILLIAM THOMSON, *M.A., F.R.S.*

I. A finite volume of incompressible inviscid fluid being given, in motion, filling a fixed, simply continuous, rigid boundary, the fact of its being in motion implies molecular rotation, or (as it may be called for brevity) vorticity. Helmholtz's law of conservation of vorticity shows that, whether the boundary be kept fixed as given, or be moved or deformed in any way, and brought back to its given shape and position, there remains in every portion of the fluid which had molecular rotation a definite constant of vorticity; and his formula for calculating energy for any given distribution of vorticity allows us to see that the energy may be varied by the supposed operation on the boundary.

II. The condition for steady motion of an incompressible inviscid fluid filling a finite fixed portion of space (that is to say, motion in which the velocity and direction of motion continue unchanged at every point of the space within which the fluid is placed) is that, with given vorticity, the energy is a thorough maximum, or a thorough minimum, or a minimax. The farther condition of *stability* is secured by the consideration of energy alone for any case of steady motion, for which the energy is a thorough maximum or a thorough minimum; because when the boundary is held fixed the energy is of necessity constant. But the mere consideration of energy does not decide the question of stability for any case of steady motion in which the energy is a minimax.

III. It is clear that, commencing with *any* given motion, the energy may be increased indefinitely by properly-designed operation on the boundary (understood that the primitive boundary is returned to). Hence, with given vorticity, there is no thorough maximum of energy in any case. There may also be *complete annulment* of the energy by operation on the boundary (with return to the primitive boundary), as we see by the following illustrations:—

1. The case of two equal, parallel, and oppositely rotating vortex columns terminated perpendicularly by two fixed parallel planes, which, by proper operation on the boundary, may be so mixed (like two eggs 'whipped' together) that, infinitely near to any portion of either, there shall be some of the other.

2. The case of a single Helmholtz ring, reduced by diminution of its aperture to an infinitely long tube coiled within the enclosure.

3. The case of a single vortex column, with two ends on the boundary, bent till its middle meets the boundary; and farther bent and extended, till it is broken into two equal and opposite vortex columns; and then farther dealt with till these two are whipped together to mutual annihilation.

IV. To avoid for the present the extremely difficult general question illustrated (or suggested) by the consideration of such cases, confine ourselves now to two-dimensional motions in a space bounded by two fixed parallel planes and a closed cylindric surface perpendicular to them, subjected to changes of figure (but always truly cylindric and perpendicular to the planes). It is obvious that, with the limitation to two-dimensional motion, the energy cannot be either infinitely small or infinitely great with any given vorticity and given cylindric figure. Hence, under the given conditions, there certainly are at least two stable steady motions. We shall, however, see farther (XI. below) that possibly in every case, except cases of a narrow, well-defined character, and certainly in many cases, there is an infinite number of stable steady motions.

V. In the present case, clearly, though there are an infinite number of unstable steady motions, there are only two stable steady motions—those of absolute maximum and of absolute minimum energy.

VI. In every steady motion, when the boundary is circular, the stream lines are concentric circles, and the fluid is distributed in co-axial cylindric layers of equal vorticity. In the stable motion of maximum energy, the vorticity is greatest at the axis of the cylinder, and is less and less outwards to the circumference. In the stable motion of minimum energy the vorticity is smallest at the axis, and greater and greater outwards to the circumference. To express the conditions symbolically, let T be the velocity of the fluid at distance r from the axis (understood that the direction of the motion is perpendicular to the direction of r); the vorticity at distance r is—

$$\tfrac{1}{2}\left(\frac{T}{r} + \frac{dT}{dr}\right).$$

If the value of this expression diminishes from $r = 0$ to $r = a$, the motion is stable, and of maximum energy. If it increases from $r = 0$ to $r = a$ the motion is stable and of minimum energy. If it increases and diminishes, or diminishes and increases, as r increases continuously, the motion is unstable.

VII. As a simplest subcase, let the vorticity be uniform through a given portion of the whole fluid, and zero through the remainder. In the stable motion of greatest energy, the portion of fluid having vorticity will be in the shape of a circular

cylinder rotating like a solid round its own axis, coinciding with the axis of the enclosure; and the remainder of the fluid will revolve irrotationally around it, so as to fulfil the condition of no finite slip at the cylindrical interface between the rotational and irrotational portions of the fluid. The expression for this motion in symbols is

$$T = \zeta r \text{ from } r = 0 \text{ to } r = b;$$

$$\text{and } T = \frac{\zeta b^2}{r} \text{ from } r = b \text{ to } r = a.$$

VIII. In the stable motion of minimum energy the rotational portion of the fluid is in the shape of a cylindric shell, inclosing the irrotational remainder, which in this case is at rest. The symbolical expression for this motion is

$$T = 0, \text{ when } r < \sqrt{(a^2 - b^2)} \text{ and } T = \zeta\left(r - \frac{a^2 - b^2}{r}\right),$$
$$\text{when } r > \sqrt{(a^2 - b^2)}.$$

IX. Let now the liquid be given in the configuration VII. of greatest energy, and let the cylindrical boundary be a sheet of a real elastic solid, such as sheet-metal with the kind of dereliction from perfectness of elasticity which real elastic solids present; that is to say, let its shape when at rest be a function of the stress applied to it, but let there be a resistance to change of shape depending on the velocity of the change. Let the unstressed shape be truly circular, and let it be capable of slight deformations from the circular figure in cross section, but let it always remain truly cylindrical. Let now the cylindric boundary be slighly deformed and left to itself, and held so as to prevent it from being carried round by the fluid. The central vortex column is set into vibration in such a manner that longer and shorter waves travel round it with less and greater angular velocity.* These waves cause corresponding waves of corrugation to travel round the cylindric bounding sheet, by which energy is consumed, and moment of momentum taken out of the fluid. Let this process go on until a certain quantity of moment of momentum has been stopped from the fluid, and now let the canister run round freely in space, and, for simplicity, suppose its material to be devoid of inertia. The whole moment of momentum is initially

$$\pi\zeta b^2(a^2 - \tfrac{1}{2}b^2);$$

It is now

$$\pi\zeta b^2(a^2 - \tfrac{1}{2}b^2) - M,$$

and continues constantly of this amount as long as the boundary is left free in space. The consumption of energy still goes on, and the way in which it goes on is this: the waves of shorter length are indefinitely multiplied and exalted till their crests run out into fine laminæ of liquid, and those of greater length are abated. Thus a certain portion of the irrotationally revolving water becomes mingled with the central vortex column. The process goes on until what may be called a vortex sponge is formed; a mixture homogeneous on a large scale, but consisting of portions of rotational and irrotational fluid, more and more finely mixed together as time advances. The mixture is, as indicated above, altogether analogous to the mixture of the substances of two eggs whipped together in the well-known culinary operation. Let b' be the radius of the cylindric vortex sponge, b being as before the radius of the original vortex column

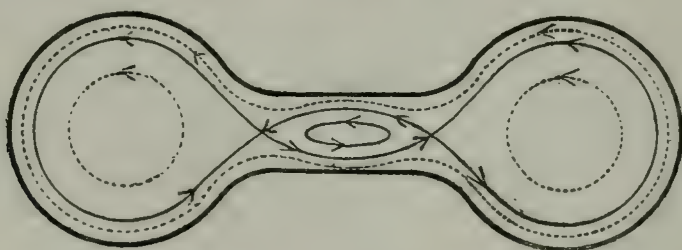
$$\tfrac{1}{2}b'^2 = \tfrac{1}{2}b^2 + \frac{M}{\zeta b^2}.$$

X. Once more, hold the cylindric case from going round in space, and continue holding it until some more moment of momentum is stopped from the fluid. Then leave it to itself again. The vortex sponge will swell by the mingling with it of an additional portion of irrotational liquid. Continue this process until the sponge occupies the whole enclosure.

* See *Proceedings of the Royal Society of Edinburgh* for 1880, or *Philosophical Magazine* for 1880: 'Vibrations of a Columnar Vortex:' Wm. Thomson.

After that continue the process further, and the result will be that each time the containing canister is allowed to go round freely in space, the fluid will tend to a condition in which a certain portion of the original vortex core gets filtered into a position next to the boundary, and the fluid within it tends to a more and more nearly uniform mixture of vortex with irrotational fluid. This central vortex-sponge, on repetition of the process of preventing the canister from going round, and again leaving it free to go round, becomes more and more nearly irrotational fluid, and the outer belt of pure vortex becomes thicker and thicker. The final condition towards which the whole tends is a belt constituted of the original vortex core now next the boundary; and the fluid which originally revolved irrotationally round it now placed at rest within it, being the condition (VIII. above) of absolute minimum energy. Begin once more with the condition (VII. above) of absolute maximum energy, and leave the fluid to itself, whether with the canister free to go round sometimes, or always held fixed, provided only it is ultimately held from going round in space; the ultimate condition is always the same, viz., the condition (VIII.) of absolute minimum energy.

XI. That there may be an infinite number of configurations of stable motions, each of them having the energy of a thorough minimum as said in IV. above, we see, by considering the case in which the cylindric boundary of the containing canister consists of two wide portions communicating by a narrow passage, as shown in the sketch. If such a canister be completely filled with irrotationally moving fluid of uniform vorticity, the stream lines must be something like those indicated in the sketch.



Hence if a small portion of the whole fluid is irrotational, it is clear that there may be a minimum energy, and therefore a stable configuration of motion, with the whole of this in one of the wide parts of the canister; or the whole in the other; or any proportion in one and the rest in the other; or a small portion in the elliptic whirl in the connecting canal, and the rest divided in any proportion between the two wide parts of the canister.

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5. *On Inverse Figures in Geometry. By* Professor H. J. S. SMITH, *M.A., F.R.S.*

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6. *On a Mathematical Solution of a Logical Problem. By* Professor H. J. S. SMITH, *M.A., F.R.S.*

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7. *On the Distribution of Circles on a Sphere. By* Professor H. J. S. SMITH, *M.A., F.R.S.*

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8. *Notes on Non-Euclidian Geometry. By* ROBERT S. BALL, *LL.D., F.R.S.*

The problem I propose to consider relates to the kinematics of a rigid body in non-Euclidian space. I can hardly say that the communication is exactly novel, as

the same problem has been considered by Lindemann. I think, however, that a purely geometrical method of looking at the question may be of interest.

The most general displacement of a rigid body is a rotation about an axis combined with a rotation about the polar axis with regard to the absolute. These two rotations form the unit of displacement. My problem is the determination of the single unit of displacement, which is equivalent to the joint effect of two displacements, all being small. This, it will be observed, includes every problem of the composition of forces or rotations in non-Euclidian space.

Each of the component units involves a pair of conjugate polars, A,A′ and B,B′, and we require to find a pair of conjugate polars C,C′ the rotations around which shall be equivalent to the given rotations about A,A′ and B,B′.

Draw the common transversals X and X′ to the four rays A,B,A′,B′, then it can easily be shown that the effect of the given displacements on four points P Q R S on X will move those points on right of lines directed towards P′ Q′ R′ S′ on X′, so that the anharmonic ratio of P Q R S is equal to that of P′ Q′ R′ S′.

On X there are two critical points, L and M, which are characterised by the circumstance that they start in the same direction whether the displacement be A, A′ or B, B′. It is therefore necessary that C, C′ shall be such as to start L and M in the same direction. This condition will enable C and C′ to be determined.

Let the two given displacements convey L and M to L′ and M′, then C and C′ are two generators of the hyperboloid of which X, X′, and L′ M′, are three generators of the other system. But when two hyperboloids are such that a pair of generators of one system on one hyherboloid are conjugate polars of the other, then a pair of generators of the other system are also conjugate polars. Observing that X and X′ are conjugate polars of the absolute we therefore have C and C′ completely determined.

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9. *On the deduction of Trigonometrical from Elliptic Function Formulæ. By* J. W. L. Glaisher, *M.A., F.R.S.*

In any elliptic function identity, connecting sn's, cn's, and dn's, we may, of course, as is well known, put $k = 0$, when the sn's and cn's become respectively sines and cosines and the dn becomes unity. But we may also expand the elliptic functions in powers of k^2, and equate the coefficients of k^2, k^4, &c., to zero. Considering only terms as far as k^2, it can be shown that

$$\operatorname{am} u = u - \tfrac{1}{4}k^2u + \tfrac{1}{8}k^2\sin 2u$$

so that

$$\begin{aligned}\operatorname{sn} u &= \sin u - \tfrac{1}{4}k^2u\cos u + \tfrac{1}{8}k^2\sin 2u\cos u\\ \operatorname{cn} u &= \cos u + \tfrac{1}{4}k^2u\sin u - \tfrac{1}{8}k^2\sin 2u\sin u\\ \operatorname{dn} u &= 1 - \tfrac{1}{2}k^2\sin^2 u\end{aligned}$$

Now the terms $-\tfrac{1}{4}k^2u\cos u$ and $\tfrac{1}{4}k^2u\sin u$, in which the argument appears outside, will generally lead to terms which, on this account, are separately equal to zero, so that in deducing trigonometrical from elliptic function formulæ (in which the arguments do not appear as external factors), we may put

$$\left.\begin{aligned}\operatorname{sn} u &= \sin u\,(1 + \tfrac{1}{4}k^2\cos^2 u)\\ \operatorname{cn} u &= \cos u\,(1 - \tfrac{1}{4}k^2\sin^2 u)\\ \operatorname{dn} u &= \qquad 1 - \tfrac{1}{2}k^2\sin^2 u\end{aligned}\right\}\ \ldots\ (1)$$

and equate the powers of k^2 to zero.

As an example, consider the elliptic function identity

$$\begin{aligned}&\operatorname{sn}\beta\operatorname{sn}\gamma\operatorname{sn}(\beta-\gamma) + \operatorname{sn}\gamma\operatorname{sn}\alpha\operatorname{sn}(\gamma-\alpha) + \operatorname{sn}\alpha\operatorname{sn}\beta\operatorname{sn}(\alpha-\beta)\\ &\quad + \operatorname{sn}(\beta-\gamma)\operatorname{sn}(\gamma-\alpha)\operatorname{sn}(\alpha-\beta) = 0;\end{aligned}$$

putting $k = 0$, we obtain the well-known trigonometrical identity

$$\begin{aligned}&\sin\beta\sin\gamma\sin(\beta-\gamma) + \sin\gamma\sin\alpha\sin(\gamma-\alpha) + \sin\alpha\sin\beta\sin(\alpha-\beta)\\ &\quad + \sin(\beta-\gamma)\sin(\gamma-\alpha)\sin(\alpha-\beta) = 0,\ \ldots\ (2)\end{aligned}$$

but substituting for the sn's by (1), and equating the coefficient of k^2 to zero, we have

$$\begin{aligned}&\sin\beta\sin\gamma\sin(\beta-\gamma)\left[\cos^2\beta+\cos^2\gamma+\cos^2(\beta-\gamma)\right]\\&+\sin\gamma\sin a\sin(\gamma-a)\left[\cos^2\gamma+\cos^2 a+\cos^2(\gamma-a)\right]\\&+\sin a\sin\beta\sin(a-\beta)\left[\cos^2 a+\cos^2\beta+\cos^2(a-\beta)\right]\\&+\sin(\beta-\gamma)\sin(\gamma-a)\sin(a-\beta)\left[\cos^2(\beta-\gamma)+\cos^2(\gamma-a)+\cos^2(a-\beta)\right]=0,\end{aligned}$$

which, in virtue of (2), may be written

$$\begin{aligned}&\sin\beta\sin\gamma\sin(\beta-\gamma)\left[\sin^2\beta+\sin^2\gamma+\sin^2(\beta-\gamma)\right]\\&+\sin\gamma\sin a\sin(\gamma-a)\left[\sin^2\gamma+\sin^2 a+\sin^2(\gamma-a)\right]\\&+\sin a\sin\beta\sin(a-\beta)\left[\sin^2 a+\sin^2\beta+\sin^2(a-\beta)\right]\\&+\sin(\beta-\gamma)\sin(\gamma-a)\sin(a-\beta)\left[\sin^2(\beta-\gamma)+\sin^2(\gamma-a)+\sin^2(a-\beta)\right]\\&=0\ldots(3)\end{aligned}$$

Similarly from

$$\begin{aligned}&\operatorname{sn} a\operatorname{sn}(\beta-\gamma)+\operatorname{sn}\beta\operatorname{sn}(\gamma-a)+\operatorname{sn}\gamma\operatorname{sn}(a-\beta)\\&+k^2\operatorname{sn} a\operatorname{sn}\beta\operatorname{sn}\gamma\operatorname{sn}(\beta-\gamma)\operatorname{sn}(\gamma-a)\operatorname{sn}(a-\beta)=0\end{aligned}$$

we have, by putting $k=0$,

$$\sin a\sin(\beta-\gamma)+\sin\beta\sin(\gamma-a)+\sin\gamma\sin(a-\beta)=0,$$

and, by equating to zero the coefficient of k^2,

$$\begin{aligned}&\sin a\sin(\beta-\gamma)\left[\sin^2 a+\sin^2(\beta-\gamma)\right]\\&+\sin\beta\sin(\gamma-a)\left[\sin^2\beta+\sin^2(\gamma-a)\right]\\&+\sin\gamma\sin(a-\beta)\left[\sin^2\gamma+\sin^2(a-\beta)\right]\\&-4\sin a\sin\beta\sin\gamma\sin(\beta-\gamma)\sin(\gamma-a)\sin(a-\beta)=0\end{aligned}$$

If the object be, not to deduce trigonometrical formulæ from elliptic function formulæ, but to verify the latter, the formulæ deduced by equating to zero the coefficient of k^2 obtained by means of (1), generally afford a much better verification than is obtained by merely putting $k=0$.

It may be mentioned that (3) may be easily verified by use of (2) and of the formula

$$\sin^2 x+\sin^2 y+\sin^2(x-y)=2-2\cos x\cos y\cos(x-y).$$

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10. *On Plane and Spherical Curves of the Fourth Class with Quadruple Foci. By* HENRY M. JEFFERY, *F.R.S.*

I. ON PLANE CLASS-QUARTICS.

1. All quartics with quadruple foci may be expressed by the geometrical relation

$$\kappa p^4=qr+\lambda$$

if the line-coordinates p, q, r denote the quadruple focus P, and Q, R the foci of the satellite-conic.

It is proposed to examine every possible quartic in a group, in which P, Q, R remain unaltered, while the parameters, κ, λ, vary indefinitely.

2. When there are critical bitangential quartics in a group, the mutual relation of κ, λ will be exhibited in a plane curve, of which they are the coordinates.

This locus will be hereinafter designated the bounding curve, by which plane space will be divided into regions. In some regions no quartic is possible, and if κ, λ represent points on the bounding curve, critical quartics exist, with real or imaginary bi-tangents. If two branches intersect in a node or unite in a cusp, two bi-tangents will unite to form some higher singularity. In the remaining regions quartics will occur, which alter their character as κ or λ becomes zero, i.e. as the

bounding curve intersects the axes, and in other transition-cases, which will be explained in § 8.

3. Order-quartics, whether singular or non-singular, have been classified by Dr. Zeuthen, of Copenhagen ('Mathematische Annalen,' 1874), according to their depressions, characterised by a bi-tangent and two points of inflexion; such pits are termed by that eminent geometer, *folia* (although *foveæ* might be thought more expressive). So class-quartics may have four or fewer stirrup-like excrescences.

Def.—A *stapes* or *stapete* is characterised by two cusps and a crunode. By a stapete-point is meant such an excrescence in its nascent state, just as a folium-point (foveate) or a point of undulation is an incipient depression. The stapetes and folia are reciprocal, and either do or do not constitute singularities, just as the curve is regarded by its class or order.

$$Ex. \qquad \alpha^4 + 4\beta^3\gamma = o; \ 27\,(ap)^4 + 64\,(bq)^3\,cr = o.$$

These equations denote the same quartic, with one stapete-point and one folium-point. In passing from one form to the other, 8 dimensions are lost: for (α, β) is a triple stapete-point with three singularities, and (α, γ) is a point of undulation with none. Contrariwise q is the same folium point with a triple tangent, and r a point with no singularity. The same contradiction and parallelism occur in cusped cubics, which are always inflexional. So that these conclusions may be generalised. Since

$$\alpha^n + u\,\beta^{n-1}\gamma = o; \ (n-1)^{n-1}\,(ap)^n = (-\,nbq)^{n-1}\,cr,$$

denote the same curve, $n\,(n-2)$ dimensions are lost by the mergence of cusps and nodes, or of stationary and bi-tangents at the points B, C.

4. The positions of the quadruple focus P, and of the foci Q, R of the satellite-conic, will be distinguished in five families of groups.

I. P, Q, R collinear: Q, R coincident in the centre of a satellite circle.
II. P, Q, R collinear: Q, R the foci of a satellite conic.
III. P, Q, R not collinear, but Q, R at an infinite distance.
IV. P, Q, R not collinear, but Q or R at a finite distance.
V. P, Q, R unrestricted.

The special forms should be noted, when P is at an infinite distance.

5. The process adopted will be exemplified in family I., thus represented by the Boothian equation.

$$\kappa = (1 - a\xi)^2\,(\xi^2 + \eta^2) + \lambda\,(\xi^2 + \eta^2)^2.$$

P is the origin; PQ $= a$, the distance of the double focus of the satellite conic.

By partial differentiation,

$$o = \xi\,(1 - a\xi)^2 + 2\lambda\xi\,(\xi^2 + \eta^2) - a\,(1 - a\xi)\,(\xi^2 + \eta^2)$$
$$o = \eta\,(1 - a\xi)^2 + 2\lambda\eta\,(\xi^2 + \eta^2).$$

The factor $(\eta = o)$ alone yields bitangential values.

$$\text{If } \eta = o, \ 2\kappa = \xi^2\,(1 - a\xi)$$
$$2\lambda\xi^2 + (1 - a\xi)\,(1 - 2a\xi) = o.$$

If it be thought necessary, the equation to this unicursal bounding curve will be found explicitly to be a quintic

$$\left(\frac{a}{\kappa} - 18a^3 + 36\lambda\right)^2 = \left(\frac{1}{\kappa} - 14a^2 + 4\lambda\right)^2 (a^2 - 8\lambda)$$

But hereafter the explicit equation to the bounding curves will be rarely determined.

6. At a singular point on the quintic $\dfrac{d\kappa}{d\xi} = o = \dfrac{d\lambda}{d\xi}$; there are two cusps, one at infinity, when $\xi = o$, at the extremity of the (λ) axis, and another, when $3a\xi = 2$, $8\lambda = a^2$, $27a^2\kappa = 2$.

There is a single asymptote $\lambda + a^2 = o$, when $\xi = \infty$. No points of inflexion, distinct from the cusps, satisfy the condition

$$\frac{d^2\kappa}{d\xi^2}\frac{d\lambda}{d\xi} - \frac{d^2\lambda}{d\xi^2}\frac{d\kappa}{d\xi} = o.$$

7. By the aid of this bounding quintic all quartics may be exhibited, which have a quadruple focus and a satellite-circle.

If in such a group of §5, $8\lambda = a^2$, $27a^2\kappa = 2$, so that (κ, λ) is a ceratoid cusp on the bounding quintic, the quartic

$$\frac{1}{8}a^2\eta^4 + \left(\frac{5}{4}a^2\xi^2 - 2a\xi + 1\right)\eta^2 + \frac{a}{8}(9a\xi + 2)\left(\xi - \frac{2}{3a}\right)^3 = o$$

is inflexional.

In a family of such groups, the locus of the point of inflexion is the hyperbola $(108\,\kappa\lambda = 1)$.

For values of (κ, λ) on points in the neighbourhood of the cusp, the quartics are veribantangential with two cusps of the cardioid type, or acubitangential, as (κ, λ) is situated on one or other of the branches which meet at the cusp. For points within this space, the quartics consist of an oval, pierced by the hyperbolic branches of another non-stapete or smooth oval. For points beyond this space the quartics are bistapete with four, two, or no asymptotes, and also become smooth according to the position of (κ, λ). It may suffice here to state, that for other critical values of (κ, λ), one or other negative, the quartics are limaçonoid, i.e. unistapete in the nascent form, or have bicusped bi-tangents, the reciprocals of biflecnoids, i.e., are bistapete in the nascent state.

8. Non-singular quartics may change their stapetes, without passing through critical values; the stapete-points of transition are determined by aid of the Hessian of the group, or by means of the invariants S, T, equated to zero.

Let the centre of the satellite circle be at infinity. Such a group

$$\kappa = \xi^2(\xi^2 + \eta^2) + \lambda(\xi^2 + \eta^2)^2$$

has no critical bitangential quartics, but its stapetes vary with λ. The Hessian of the group is

$$(4\lambda^2 + 6\lambda + 2)\,\xi^4 + (8\lambda^2 + 8\lambda - 1)\,\xi^2\eta^2 + (4\lambda^2 + 2\lambda)\,\eta^4 = o.$$

The real values of these points, which constitute the Hessian, and of the coincident stapete-points, depend upon the auxiliary quadratic

$$32\lambda^2 + 32\lambda = 1,$$

whose roots are ·03033 and − 1·03033.

Other transition-values of λ are 0, − ·5, −1.

If λ = ·03 or − 1·03 the quartics have four stapete-points.

λ = − ·5, there are two stapete-points.

λ = 0 or − 1, there is a tacnode at infinity,

or the quadric is bistapete in its nascent state.

For intermediate or external values the quartics are quadristapete, bistapete, or nonstapete.

9. This slight sketch may suffice to explain the plan of this chapter of Plane and a corresponding chapter in Spherical Class-Quartics, which, it is hoped, may shortly find a place in the 'Quarterly Journal of Mathematics,' illustrated by the necessary diagrams.

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11. *On the equations to the real and to the imaginary directrices and latera recta of the general conic* $(a,b,c,e,f,g,h)\,(x,y1)^2 = o$; *with a note on a property of the director circle.* *By* Professor R. W. Genese, *M.A.*

Let $u \equiv ax^2 + 2hxy + by^2 + 2gn + 2fy + c = o$ be the equation to a conic referred to rectangular axes: let (a,β) be the coördinates of a focus, $x\cos\theta + y\sin\theta = p$ the corresponding directrix, and e the excentricity of the conic. The equation to the conic may therefore be written

$$(x - a)^2 + (y - \beta)^2 = e^2\,(x\cos\theta + y\sin\theta - p)^2$$

comparing with $u = o$ we get

$$\frac{1 - e^2\cos^2\theta}{a} = \frac{1 - e^2\sin^2\theta}{a} = \frac{-e^2\sin\theta\cos\theta}{h} = \frac{e^2p\cos\theta - a}{g}$$
$$= \frac{e^2p\sin\theta - \beta}{f} = \frac{a^2+\beta^2 - e^2p^2}{c} = \frac{1}{\lambda} \text{ say}$$

Eliminating e and θ we get

$$\lambda^2 - (a+b)\lambda + ab - h^2 = 0 \; . \; . \; . \; . \; . \; (A)$$

Since xy are the coördinates of *any* point on a directrix, by eliminating $p, \theta, a\,\beta, e$ from $x\cos\theta + y\sin\theta = p$ and the above equalities, we shall get the equation to the directrices

The result of the elimination is

$$\left(\frac{du}{dx}\right)^2 + \left(\frac{du}{dy}\right)^2 = 4\lambda u \; . \; . \; . \; . \; . \; (B)$$

I do not exhibit the work, because a quicker method of obtaining it will be given in the note.

Using (A), (B) may be shown to represent two *parallel* straight lines.

Thus one value of λ from (A) gives the real directrices, and the other the imaginary.

I find further that B may be resolved into

$$\sqrt{\lambda - b}\,\frac{du}{dx} + \sqrt{\lambda - a}\,\frac{du}{dy} = \pm\, 2\sqrt{\Delta} \; . \; . \; . \; . \; . \; (C)$$

$$\text{where } \Delta = \begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix}$$

and *the sign between the radicals on the left side is that of* $\frac{h}{\lambda - a}$

It follows that

$$\sqrt{\lambda - b}\,\frac{du}{dx} + \sqrt{\lambda - a}\,\frac{du}{dy} = 0 \; . \; . \; . \; . \; (D)$$

is the equation to *an* axis of the conic.

In virtue of (A) this is equivalent to

$$\left.\begin{aligned} (\lambda - b)\frac{du}{dx} + h\frac{du}{dy} &= 0 \\ \text{or} \qquad h\frac{du}{dx} + (\lambda - a)\frac{du}{dy} &= 0 \end{aligned}\right\} \; . \; . \; . \; . \; (E)$$

Having obtained the equations to *an* axis and to *a* directrix we can obtain the equation to *a* latus rectum (the polar of their intersection). Using Dr. Salmon's notation for the reciprocal coefficients the result is

$$\sqrt{\lambda - b}\,(Cx - G) + \sqrt{\lambda - a}\,(Cy - F) = \pm\,(a+b-2\lambda)\sqrt{\Delta\,C} \; . \; . \; . \; . \; (F)$$

The quantity $a+b-2\lambda$ may be shown to be the expression denoted by R in Dr. Salmon's conics (Ex. 3, Art 157, and elsewhere).

Note.

The form of the equation to the director circle of $u = o$, viz. with Dr. Salmon's notation,

$$v \equiv C\,(x^2+y^2) - 2\,G\,x - 2\,F\,y + A + B = 0$$

shows that *the straight lines joining any point on it to the circular points at infinity are conjugate with respect to the conic.*

This is a particular case of the following theorem:—If from two fixed points in the plane of a conic straight lines be drawn conjugate with respect to the conic, the locus of their intersection is, in general, a conic passing through the two given points. Also since a tangent is conjugate to any straight line passing

through its point of contact, the above locus must pass through the points of contact of the tangents to the conic from the given points. This theorem enables us to write down the equation to the known conic passing through two given points, and the points of contact of tangent from those points to a given conic.

To return to the particular case of the director circle. The tangents from the circular points at infinity intersect in the foci: the points of contact must therefore lie on the polars of the foci, i.e. on the directrices. Hence the director circle of a conic passes through the intersections of the directrices with the conic. In other words, *the directrices of a conic are the chords of intersection of the conic with its director circle.*

Their equation is therefore of the form

$$v - \mu u = o \; . \; . \; . \; . \; . \; (\mathrm{G}).$$

The conditions that this should represent parallel straight lines are found, after rejecting a factor C, F or G, each to reduce to

$$\mu^2 - \mu(a+b) + (ab - h^2) = 0$$

the quadratic (A) obtained for λ.

I have identified (G) with (B), only λ and μ must be taken as different roots of the quadratic A.

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12. *Note on the Skew Surface of the Third Order. By* Professor H. J. S. Smith, *M.A., F.R.S.*

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13. *On a kind of Periodicity presented by some Elliptic Functions. By* Professor H. J. S. Smith, *M.A., F.R.S.*

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14. *On Algebraical Expansions, of which the fractional series for the cotangent and cosecant are the limiting forms. By* J. W. L. Glaisher, *M.A., F.R.S.*

The expansions in question are:—

$$\begin{aligned}
\frac{1}{x(1^2-x^2)(2^2-x^2)\ldots(n^2-x^2)} = {} & \frac{1}{n!\,n!}\frac{1}{x} \\
& - \frac{1}{(n-1)!\,(n+1)!}\left(\frac{1}{x-1}+\frac{1}{x-1}\right) \\
& + \frac{1}{(n-2)!\,(n+2)!}\left(\frac{1}{x-2}+\frac{1}{x+2}\right) \\
& \ldots\ldots\ldots\ldots \\
& + (-)^r\frac{1}{(n-r)!\,(n+r)!}\left(\frac{1}{x-r}+\frac{1}{x+r}\right) \\
& \ldots\ldots\ldots\ldots \\
& + (-)^n\frac{1}{(2n)!}\left(\frac{1}{x-n}+\frac{1}{x+n}\right) \; . \; . \; (1)
\end{aligned}$$

$$\frac{(1^2-2^2x^2)(3^2-2^2x^2)\ldots\left\{(2n-1)^2-2^2x^2\right\}}{x(1^2-x^2)(2^2-x^2)\ldots(n^2-x^2)}$$

$$= \frac{1}{2^{2n}}\frac{(2n)!\,(2n)!}{\left\{n!\,n!\right\}^2}\frac{1}{x}$$

$$+\ \frac{1}{2^{2n}}\ \frac{(2n-2)!\,(2n+2)!}{\left\{(n-1)!\,(n+1)!\right\}^2}\left(\frac{1}{x-1}+\frac{1}{x+1}\right)$$

$$\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot$$

$$+\ \frac{1}{2^{2n}}\ \frac{(2n-2r)!\,(2n+2r)!}{\left\{(n-r)!\,(n+r)!\right\}^2}\left(\frac{1}{x-r}+\frac{1}{x+r}\right)$$

$$\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot\quad\cdot$$

$$+\ \frac{1}{2^{2n}}\ \frac{(4n)!}{\left\{(2n)!\right\}^2}\left(\frac{1}{x-n}+\frac{1}{x+n}\right).\ .\ (2)$$

Multiplying (1) and (2) throughout, by :—

$$1^2\,.\,2^2\,.\,.\,.\,n^2 \text{ and } \frac{1^2\,.\,2^2\,.\,.\,.\,n^2}{1^2\,.\,3^2\,.\,.\,.\,(2n-1)^2}$$

respectively, they become :—

$$\frac{1}{x\left(1-\frac{x^2}{1^2}\right)\left(1-\frac{x^2}{2^2}\right)\ldots\left(1-\frac{x^2}{n^2}\right)}=\frac{1}{x}-\frac{1}{1+\frac{1}{n}}\left(\frac{1}{x-1}+\frac{1}{x+1}\right)$$

$$+\frac{1-\frac{1}{n}}{\left(1+\frac{1}{n}\right)\left(1+\frac{2}{n}\right)}\left(\frac{1}{x-2}+\frac{1}{x+2}\right)$$

$$-\frac{\left(1-\frac{1}{n}\right)\left(1-\frac{2}{n}\right)}{\left(1+\frac{1}{n}\right)\left(1+\frac{2}{n}\right)\left(1+\frac{3}{n}\right)}\left(\frac{1}{x-3}+\frac{1}{x+3}\right)$$

$$+\ \&c.$$

$$\frac{\left(1-\frac{2^2x^2}{1^2}\right)\left(1-\frac{2^2x^2}{3^2}\right)\ldots\left(1-\frac{2^2x^2}{(2n-1)^2}\right)}{x\left(1-\frac{x^2}{1^2}\right)\left(1-\frac{x^2}{2^2}\right)\ldots\left(1-\frac{x^2}{n^2}\right)}=\frac{1}{x}$$

$$+\frac{1}{1+\frac{1}{n}}\ \frac{1+\frac{1}{2n}}{1-\frac{1}{2n}}\left(\frac{1}{x-1}+\frac{1}{x+1}\right)$$

$$+\frac{1-\frac{1}{n}}{\left(1+\frac{1}{n}\right)\left(1+\frac{2}{n}\right)}\ \frac{\left(1+\frac{1}{2n}\right)\left(1+\frac{3}{2n}\right)}{\left(1-\frac{1}{2n}\right)\left(1-\frac{3}{2n}\right)}\left(\frac{1}{x-2}+\frac{1}{x+2}\right)$$

$$+\ \&c.$$

which, when n is made infinite, give in the limit

$$\frac{\pi}{\sin\,\pi x}=\frac{1}{x}-\frac{1}{x-1}-\frac{1}{x+1}+\frac{1}{x-2}+\frac{1}{x+2}-\ \&c.$$

$$\pi\cot\pi x=\frac{1}{n}+\frac{1}{x-1}+\frac{1}{x+1}+\frac{1}{x-2}+\frac{1}{x+2}+\ \&c.$$

viz., on writing $\frac{x}{\pi}$ for x,

$$\frac{1}{\sin x}=\frac{1}{x}-\frac{1}{x-\pi}-\frac{1}{x+\pi}+\frac{1}{x-2\pi}+\frac{1}{x+2\pi}-\ \&c.$$

$$\cot x = \frac{1}{x} + \frac{1}{x-\pi} + \frac{1}{x+\pi} + \frac{1}{x-2\pi} + \frac{1}{x+2\pi} + \&c.$$

which are the fractional series referred to in the title.

The formulæ (1) and (2) may be established by the ordinary process for resolving an expression into partial fractions; or by means of the theorem:—If

$$\frac{A_0}{x} + \frac{A_1}{x+1} + \frac{A_2}{x+2} \dots + \frac{A_n}{x+n},$$

where $A_0, A_1, \dots A_n$, are any coefficients independent of x, be denoted by $\phi(x)$, then

$$\begin{aligned} -x\phi(x)\,\phi(-x) = \frac{A_0^2}{x} &+ A_1\phi(1) \left\{ \frac{1}{x-1} + \frac{1}{x+1} \right\} \\ &+ 2A_2\phi(2) \left\{ \frac{1}{x-2} + \frac{1}{x+2} \right\} \\ &\quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ &+ rA_r\ (r) \left\{ \frac{1}{x-r} + \frac{1}{x+r} \right\} \\ &\quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ &+ nA_n\phi(n) \left\{ \frac{1}{x-n} + \frac{1}{x+n} \right\}. \end{aligned}$$

This theorem applied to the expansions

$$\frac{1}{x(x+1)\dots(x+n)} = \frac{1}{n!}\,\frac{1}{x} - \frac{1}{(n-1)!}\,\frac{1}{x+1} + \frac{1}{2!\,(n-2)!}\,\frac{1}{x+2} \dots + (-)^n\frac{1}{n!}\,\frac{1}{x+n}$$

$$\frac{(2x+1)(2x+3)\dots(2x+2n-1)}{x(x+1)\dots(x+n)} = \frac{1}{2^n}\,\frac{(2n)!}{(n!)^2}\,\frac{1}{x} + \frac{1}{2^n}\,\frac{2!\,(2n-2)!}{(1!\,(n-1)!)^2}\,\frac{1}{x+1} \dots + \frac{1}{2^n}\,\frac{(2r)!\,(2n-2r)!}{(r!\,(n-r)!)^2}\,\frac{1}{x+r} \dots + \frac{1}{2^n}\,\frac{(2n)!}{(n!)^2}\,\frac{1}{x+n}$$

gives at once the formulæ (1) and (2).*

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15. *Note on a Trigonometrical Identity involving products of Four Sines.* *By* J. W. L. Glaisher, *M.A., F.R.S.*

In a paper in the 'Messenger of Mathematics' (vol. x. p. 26), the author had drawn attention to the following identity:—

$$\begin{aligned} &\sin a\ \sin b\ \sin c\ \sin d \\ &= \sin a'\ \sin b'\ \sin c'\ \sin d' \\ &+ \sin a''\ \sin b''\ \sin c''\ \sin d'' \end{aligned}$$

where a, b, c, d are any four quantities, and $a', b', c', d', a'', b'', c'', d''$ eight quantities derived from them by the equations

$$\begin{aligned} a' &= \tfrac{1}{2}(-a+b+c+d), & a'' &= \tfrac{1}{2}(a+b+c+d), \\ b' &= \tfrac{1}{2}(\ \ a-b+c+d), & b'' &= \tfrac{1}{2}(a+b-c-d), \\ c' &= \tfrac{1}{2}(\ \ a+b-c+d), & c'' &= \tfrac{1}{2}(a-b+c-d), \\ d' &= \tfrac{1}{2}(\ \ a+b+c-d), & d'' &= \tfrac{1}{2}(a-b-c+d), \end{aligned}$$

and in this note he pointed out that this was a particular case of a more general formula involving products of four sines.

The foregoing identity may be written

$$\begin{aligned} &\sin a \sin b \sin c \sin d \\ &= \sin(\sigma-a)\sin(\sigma-b)\sin(\sigma-c)\sin(\sigma-d) \\ &+ \sin\sigma\sin(\sigma-b-c)\sin(\sigma-b-d)\sin(\sigma-c-d) \ \dots\dots (1) \end{aligned}$$

* The paper is printed *in extenso* in the *Quarterly Journal of Mathematics*, vol. xvii, pp. 211–226.

where

$$\sigma = \tfrac{1}{2}(a + b + c + d)$$

and the more general identity is

$$\begin{aligned} &\sin\alpha \sin\beta \sin\gamma \sin\delta \\ &- \sin(\alpha + \lambda)\sin(\beta + \lambda)\sin(\gamma + \lambda)\sin(\delta + \lambda) \\ &+ \sin\lambda \sin(\alpha + \delta + \lambda)\sin(\beta + \delta + \lambda)\sin(\gamma + \delta + \lambda) \\ &- \sin\delta \sin\lambda \sin(\delta + \lambda)\sin(\alpha + \beta + \gamma + \delta + 2\lambda) = 0 \quad \ldots\ldots\ldots (2) \end{aligned}$$

where $\alpha, \beta, \gamma, \delta, \lambda$ are any five quantities. The formula (1) is the particular case of (2) obtained by putting

$$\lambda = -\tfrac{1}{2}(\alpha + \beta + \gamma + \delta)$$

The formula (2) may be written

$$\begin{aligned} &\sin(a - f)\sin(a - g)\sin(a - h)\sin(b - c) \\ &+ \sin(b - f)\sin(b - g)\sin(b - h)\sin(c - a) \\ &+ \sin(c - f)\sin(c - g)\sin(c - h)\sin(a - b) \\ &+ \sin(b - c)\sin(c - a)\sin(a - b)\sin(a + b + c - f - g - h) = 0 \,.\, (3) \end{aligned}$$

and in this form it is in effect due to Prof. Cayley and Mr. R. F. Scott: viz., in the 'Messenger,' vol. v. p. 164, Prof. Cayley stated that a certain determinant was equal to zero, if a condition, equivalent to $a + b + c = f + g + h$, was fulfilled; and in vol. viii. p. 155, Mr. R. F. Scott evaluated this determinant, without this restriction, the developed result being equivalent to (3).

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16. *On the Periods of the First Class of Hyper-elliptic Integrals.* *By* William R. Roberts, *M.A.*

I investigate the periods of hyper-elliptic functions by a method analogous to that which has been adopted by Schloemilch for the determination of the periods of elliptic integrals. By this method I determine the periodicity of hyper-elliptic integrals without integrating the equations.

$$(1) \quad \ldots \quad \begin{aligned} f(z_1)\,dz_1 + f(z_2)\,dz_2 + f(z_3)\,dz_3 &= 0 \\ f(z_1)\,z_1^2 dz_1 + f(z_2)\,z_2^2 dz_2 + f(z_3)\,dz_3 &= 0 \end{aligned}$$

where

$$f(z) = \frac{1}{\sqrt{(1-z^2)(1-k''^2z^2)(1-k'^2z^2)(1-k^2z^2)}}$$

I first determine the general value of the integral $\int_0^z f(z)dz$, and find it depends on four integrals, which I call respectively, 2Ψ, 2Ξ, $2i\Omega$, and $2i\Psi$; and in a similar manner I arrive at the general value of the integral $\int_0^z f(z)z^2dz$. The mode of investigation which I adopt for the determination of these integrals affords a proof that the equation

$$z = (-1)^l z^1$$

satisfies both the transcendental equations.

$$(2) \quad \begin{cases} \displaystyle\int_0^z f(z)dz + 2l\Psi + 2m\Xi + 2\lambda i\Omega + 2\mu i\Psi = \int_0^{z'} f(z)dz \\ \displaystyle\int_0^z z^2 f(z)dz + 2l\Psi' + 2m\Xi' + 2\lambda i\Omega' + 2\mu i\Psi' = \int_0^{z'} z^2 f(z)dz \end{cases}$$

By a series of transformations I proceed to show that the following equations:—

$$\sqrt{1 - z^2} \quad = (-1)^{l+\lambda}\sqrt{1-z'^2}$$

$$\sqrt{1 - k''^2z^2} = (-1)^{\lambda+m}\sqrt{1-k''^2z'^2}$$

(3) . . . . . $\sqrt{1-k'^2z^2} = (-1)^{m+\mu}\sqrt{1-k'^2z'^2}$

$\sqrt{1-k^2z^2} = (-1)^{\mu+l}\sqrt{1-k^2z'^2}$

are agreeable to both the transcendental equations (2).

I then consider the transcendental system :—

$$(4)\ \int_0^{z_1} f(z)dz + \int_0^{z_2} f(z)dz + 2l\Psi + 2n\Xi + 2\lambda i\Omega + 2\mu i\Psi = \int_0^{z_1'} f(2)d + \int_0^{z_2'} f(z)dz$$

$$\int_0^{z_1} z^2 f(z)dz + \int_0^{z_2} z^2 f(z)dz + 2l\Psi' + 2m\Xi' + 2\lambda i\Omega' + 2\mu i\Psi' = \int_0^{z_1'} z^2 f(z)dz + \int_0^{z'_2} z'f(z)dz$$

and deduce its equivalent algebraic system.

Finally I put $U = \int_0^{z_1} f(z)dz + \int^{z_2} f(z)dz$

$$V = \int_0^{z_1} z^2 f(z)dz + \int_0^{z_2} z^2 f(z)dz$$

and I write $z_1z_2 = F(U, V)$, and show that $F(U,V)$ is a periodic function of two variables U and V, each of which has four periods, two real and two imaginary; the nature of the periodicity of which I discuss in the investigation of the general values of the integrals $\int_0^z f(z)dz$ and $\int_0^z z^2 f(z)dz$.

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17. *On the Integral of Laplace's Equation in Finite Terms. By the* Rev. S. Earnshaw, *M.A.*

The Integral of Laplace's Equation.

The equation to which this title refers is the following:—

$$\frac{d^2u}{dx^2} + \frac{d^2u}{dy^2} + \frac{d^2u}{dz^2} = 0, \dots (1)$$

and I am desirous of the three following propositions being communicated to Section A, at the meeting of the British Association at Swansea.

Prop. A.—The independent variables x, y, z are in this equation not necessarily the coördinates of some point P, in space referred to a fixed rectangular system of coördinate axes Ox, Oy, Oz. We shall, however, hypothetically treat them as such; and therefore we say that

$$OP^2 = r^2 = x^2 + y^2 + z^2.$$

Now from O draw any two lines, OA, OB, at right angles to each other, and let ξ, η represent the lengths of the rectangular projections of OP upon these two arbitrary lines; then will the following be a general integral of Laplace's equation given above,

$$u = A\epsilon^{a\xi}\cos(a\eta + b) \dots (2)$$

in which A, a, b are arbitrary constants which have no reference whatever to the arbitrary positions of OA, OB.

It will also be noticed that, b being arbitrary, the integral (2) is equivalent to two conjugate integrals, and may be more completely written thus,

$$u = \epsilon^{a\xi}(\mathrm{A}\cos a\eta + \mathrm{B}\sin a\eta).$$

The generality of this integral is due to the circumstance that the two lines OA, OB (on which ξ, η are the projections of r) are perfectly arbitrary as to their directions in space, while ξ, η are entirely dependent, for their values in terms of x, y, z, on the positions of OA, OB.

Every different position of OA, OB, or of either of them, will give a special integral, though every such special integral will be of the common type (2). Each special integral will have its own arbitrary (or special) constants in the place of A, a, b; and any of such special integrals may be formed by addition into a group, which group will be an integral of equation (1).

There is no limit to the number of groups, but every group will be composed of integrals of the type (2); and it is in reference to this property that we designate (2) the *general* integral. We may mention that $\xi = r\cos \mathrm{AOP}$ and $\eta = r\cos \mathrm{BOP}$, and these cosines are easily expressed in terms of x, y, z, and the arbitrary angles which OA, OB make with the coördinate axes.

Prop. B.—If now a third line OC be drawn at right angles to both the lines OA, OB; and if ζ be the length of the projection of r on OC, then will the following differential equation hold good *always, i.e.* whatever be the positions of OA, OB, OC,

$$\frac{d^2u}{d\xi^2} + \frac{d^2u}{d\eta^2} + \frac{d^2u}{d\zeta^2} = 0,$$

from which it follows, that if we possess any integral $\mathrm{F}(x, y, z)$ of the equation (1) we may write in this integral, instead of x, y, z, the values of ξ, η, ζ in terms of x, y, z; and the integral F, though much changed thereby, will still be an integral of the equation (1).

As a very simple example we may mention this, that if $\mathrm{F}(x, y, z)$ be an integral, so likewise will $\mathrm{F}(x\cos a + y\sin a, y\cos a - x\sin a, z)$ be an integral of equation (1), though we have written $x\cos a + y\sin a$ and $y\cos a - x\sin a$ instead of x and y; and $a =$ is an arbitrary constant. And, thus, if the integral $\mathrm{F}(x, y, z)$ be only a *particular* integral this introduction of an additional arbitrary constant a, which it did not possess before, will advance it a step towards generality.

Prop. C.—The independent variables of equation (1) have usually been changed by assuming two angles, θ, ϕ, such that $x = r\sin\theta\cos\phi$, $y = r\sin\theta\sin\phi$, and $z = r\cos\theta$. It is somewhat more convenient in the work of integration to change the angle θ for its complement to a right angle. Thus we shall make the following change of independent variables,

$$x = r\cos\theta\cos\phi, y = r\cos\theta\sin\phi, z = r\sin\theta.$$

The transformed equation on these assumptions is

$$r^2\frac{d^2u}{dr^2} + 2r\frac{du}{dr} + \frac{d^2u}{d\theta^2} - \tan\theta\frac{du}{d\theta} + \sec^2\theta\frac{d^2u}{d\phi^2} = 0,$$

and of this the following is the general integral,

$$u = \mathrm{F}\left(r\cos\theta\,.\,\epsilon^{i\phi}\right) + \frac{1}{r}f\left(r\sec\theta\,.\,\epsilon^{-i\phi}\right)\,.\,.\,.\,.\,(3)$$

i is defined by the equation $i^2 = -1$, and F, f are arbitrary functions.

The form of the transformed differential equation shows that $\frac{du}{d\phi}$ is also an integral of it. Hence we may replace the second term of (3) by its differential coefficient with regard to ϕ; so that we may present (3) in the following form:—

$$u = \mathrm{F}\left(r\cos\theta\,.\,\epsilon^{i\phi}\right) + \epsilon^{-i\phi}\sec\theta f\left(r\sec\theta\,.\,\epsilon^{-i\phi}\right)\,.\,.\,.\,.\,(4).$$

I am not aware that the integral of the above equation has ever before been presented in finite terms; on which account I make this communication to the British Association.[1]

MONDAY, AUGUST 30.

The following Reports and Papers were read:—

1. *Report of the Committee on Tidal Observations in the English Channel, &c.* See Reports, p. 390.

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2. *Report of the Committee on Luminous Meteors.*—See Reports, p. 39.

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3. *Report of the Committee on the question of Improvements in Astronomical Clocks.*—See Reports, p. 56.

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4. *On a Septum permeable to Water and impermeable to Air, with practical applications to a Navigational Depth-gauge. By* Professor Sir WILLIAM THOMSON, *M.A., F.R.S.*

A small quantity of water in a capillary tube, with both ends in air, acts as a perfectly air-tight plug against difference of pressure of air at its two ends, equal to the hydrostatic pressure corresponding to the height at which water stands in the same capillary tube when it is held upright, with one end under water and the other in air. And if the same capillary tube be held completely under water, it is perfectly permeable to the water, opposing no resistance except that due to viscidity, and permitting a current of water to flow through it with any difference of pressure at its two ends, however small. In passing it may be remarked that the same capillary tube is, when not plugged by liquid, perfectly permeable to air.

A plate of glass, or other solid, capable of being perfectly wet by water, with a hole bored through it, acts similarly in letting air pass freely through it when there is no water in the hole; and letting water pass freely through it when it is held under water; and resisting a difference of air-pressures at the two sides of it when the hole is plugged by water. The difference of air-pressures on the two sides which it resists is equal to the hydrostatic pressure corresponding to the rise of water in a capillary tube of the same diameter as the narrowest part of the hole. Thus a metal plate with a great many fine perforations, like a very fine rose for a watering-can for flowers, fulfils the conditions stated in the title to this communication. So does very fine wire cloth. The finer the holes, the greater is the difference of air-pressures balanced, when they are plugged with water. The shorter the length of each hole the less it resists the passage of water when completely submerged; and the greater the number of holes, the less is the whole resistance to the permeation of water through the membrane.

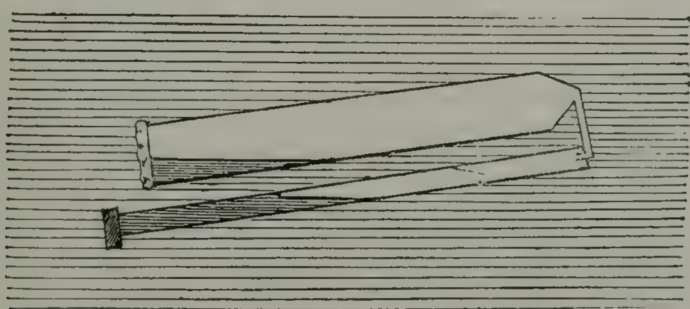
Hence, clearly, the object indicated in the title is more perfectly attained the thinner the plate and the smaller and more numerous the holes. Very fine wire cloth would answer the purpose better than any metal plate with holes drilled through it; and very fine closely-woven cotton cloth, or cambric, answers better than the finest wire cloth. The impenetrability of wet cloth to air is well known to laundresses, and to every naturalist who has ever chanced to watch their operations. The quality of dry cloth to let air through with considerable freedom, and wet cloth to resist it, is well known to sailors, wet sails being sensibly more

[1] The original paper is ready for the press, and will shortly be published.

effective than dry sails (and particularly so in the case of old sails, and of sails of thin and light material).

An illustration was shown to the meeting by taking an Argand lamp-funnel, with a piece of very fine closely-woven cotton cloth tied over one end of it. When the cloth was dry, and the other end dipped under water, the water rose with perfect freedom inside, showing exceedingly little resistance to the passage of air through the dry cloth. When it was inverted, and the end guarded by the cloth held under water, the water rose with very great freedom, showing exceedingly little resistance to the permeation of water through the cloth. The cloth being now wet, and the glass once more held with its other end under water, the cloth now seemed perfectly air-tight, even when pressed with air-pressure corresponding to nine inches of water, by forcing down the funnel, which was about nine inches long, till the upper end was nearly submerged. When it was wholly submerged, so that there was air on one side and water on the other the resistance to permeation of air was as decided as it was when the cloth, very perfectly wet, had air on each side of it.

Once more, putting the cloth end under water; holding the tube nearly horizontal, and blowing by the mouth applied to the other end:—the water which had risen into the funnel before the mouth was applied, was expelled. After that no air escaped until the air-pressure within exceeded the water pressure on the outside of the cloth by the equivalent of a little more than nine inches of water; and when blown with a pressure just a very little more than that which sufficed to produce a bubble from any part of the cloth, bubbles escaped in a copious torrent from the whole area of the cloth.



Water indicated by horizontal shading ; air by white paper.

The accompanying sketch represents the application to the Navigational Depth-gauge. The wider of the two communicating tubes, shown uppermost in the sketch, has its open mouth guarded by very fine cotton cloth tied across it. The tube shown lower in the diagram is closed for the time of use by a stopper at its lower end. A certain quantity of water (which had been forced into it during the descent of the gauge to the bottom of the sea) is retained in it while the gauge is being towed up to the surface in some such oblique position as that shown in the sketch. While this is being done the water in the wide tube is expelled by the expanding air. The object of the cloth guard is to secure that this water is expelled to the last drop before any air escapes; and that afterwards, while the gauge is being towed wildly along the surface from wave to wave by a steamer running at fourteen or sixteen knots, not a drop of water shall re-enter the instrument.

5. *On the Effect of Oil in destroying Waves on the Surface of Water.* *By* Professor Osborne Reynolds, *M.A.*, *F.R.S.*

This paper contained a short account of an investigation from which it appeared that the effect of oil on the surface of water to prevent wind-waves and destroy waves already existing, was owing to the surface-tension of the water over which the oil spread varying inversely as the thickness of the oil, thus introducing

tangential stiffness into the oil-sheet, which prevented the oil taking up the tangential motion of the water beneath. Several other phenomena were also mentioned. The author hopes shortly to publish a full account of the investigation.

6. *Experiments on thin Films of Water, with regard to their absorption of Radiant Heat. By the* Hon. F. A. R. Russell.

The experiments, the general results of which are given below, were made with the object of ascertaining the diathermancy of water in very thin films, and these experiments afforded incidentally an opportunity of observing the behaviour of films subject to varying conditions.

The arrangement of instruments was similar to that illustrated at p. 383 of Prof. Tyndall's 'Heat as a Mode of Motion.' The instruments used were: a dead-beat mirror galvanometer and scale, a thermopile, and a screen. The soap film was carried by a piece of a cork sole perforated by a hole slightly larger than the hole in the screen, about 1½ inches in diameter. The sources of heat were (1) a copper or iron ball heated from behind by a small gas flame; (2) a common gas flame from a Bunsen burner, and (3) a hydrogen flame in air.

The film was mostly made from a solution of about half a drachm of shavings of Castile soap, dissolved 5 to 15 minutes in about 5 cubic inches of water, at 60° Fahrenheit.

The film soon after being placed perpendicularly at the orifice in the screen exhibited coloured bands, which descended in regular succession until the last band appeared, which contained a bright blue line. The descent of the bands continued at a slackened rate till the grey, and finally the black, occupied a portion of the upper half of the film, which half was alone subject to experiment. A condition more or less of equilibrium then prevailed, the tension of the black portion counteracting the force of gravity. A light yellow or bronze was always the last colour to appear, and preceded the white or grey, which again was succeeded by black. When there was any black in the film, the bursting of the film was marked by a slight click or snapping sound. The best films lasted frequently between 10 and 30 minutes, and sometimes the black portion alone was under observation 15 or 20 minutes.

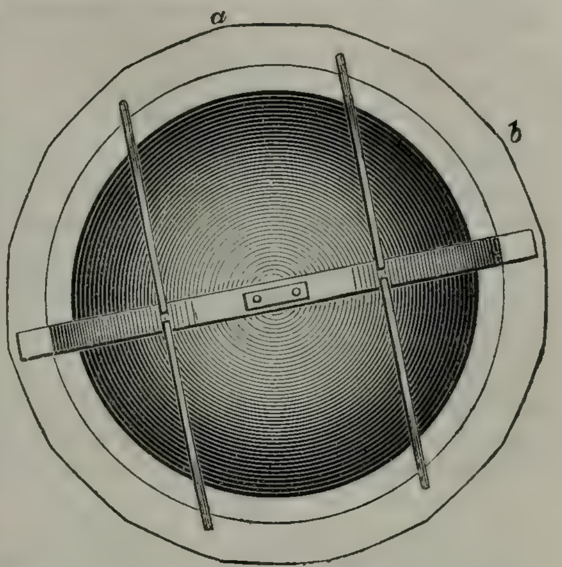
The following table shows the absorption per cent. for each of the three sources of heat, and the thickness of the film, as derived from a table in Watts's 'Dictionary of Chemistry,' giving Newton's thicknesses of thin films of air, water, and glass. A table in Cooke's 'New Chemistry' gives the thicknesses of soap-films as considerably greater than those stated in Newton's table. The 'light film' of Cooke corresponds to my 'grey,' and his 'grey' to my 'fine grey.' Newton's 'white' corresponds to my 'grey.' The refractive index of the solution used by me was 1·34 and 1·35, a little higher than that of pure water.

State of Film	Metal	Coal Gas	Hydrogen	Thickness of Film in millionths of an inch
Last band alone[1]	9?	·8?	—	8·3
Bronze	6	5·7	—	5·2
All grey (white)	4·7	—	4·5	3·9
Fine grey	—	3·4	—	1·8
Half grey, half black	—	2·9	—	2·3
Two-thirds black, one-third grey	—	1·6	1·6	1·8
Half fine grey, half black	0·7	—	—	1·34
Black and slight fine grey	—	—	1·2	
Fine grey and black, or all black	0·29	—	—	0·75
All black	0·29	1·5	0·6	

[1] The absorption in this case is deduced from that of a film containing a portion of grey, the absorption of the grey being known.

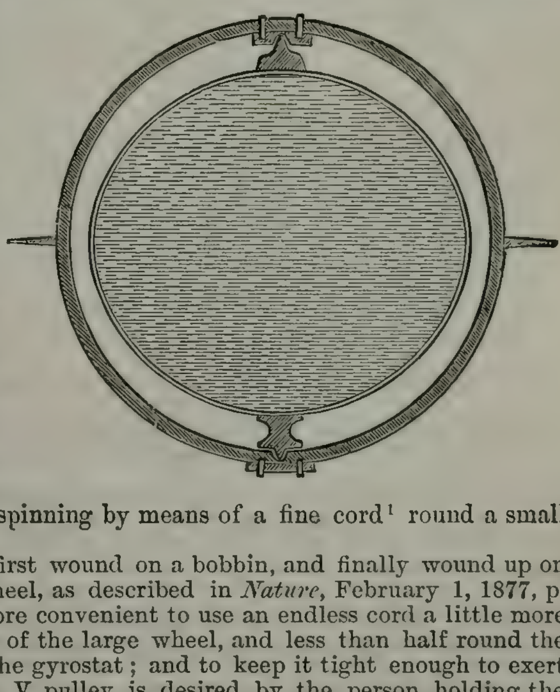
7. *On an Experimental Illustration of Minimum Energy in Vortex Motion.* *By* Professor Sir William Thomson, *M.A.*, *F.R.S.*

This illustration consists of a liquid gyrostat of exactly the same construction as that described and represented by the annexed drawing, repeated from 'Nature,' February 1, 1877, pp. 297–298, with the difference that the figure of the shell is prolate instead of oblate. The experiment was in fact conducted with the actual apparatus which was exhibited to the British Association at Glasgow in 1876, altered by the substitution of a shell having its equatorial diameter about $\frac{9}{10}$ of its axial diameter, for the shell with axial diameter $\frac{9}{10}$ of equatorial diameter which was used when the apparatus was shown as a successful gyrostat. The oblate and prolate shells were each of them made from the two hemispheres of sheet copper which plumbers solder together to make their globular floaters. By a little hammering it is easy to alter the hemispheres to the proper shapes to make either the prolate or the oblate figure.



←——— 7. INCHES ———→

Theory had pointed out that the rotation of a liquid in a rigid shell of oval figure, being a configuration of maximum energy for given vorticity, would be unstable if the containing vessel is left to itself supported on imperfectly elastic supports, although it would be stable if the vessel were held absolutely fixed, or borne by perfectly elastic supports, or left to itself in space unacted on by external force; and it was to illustrate this theory that the oval shell was made and filled with water and placed in the apparatus. The result of the first trial was literally startling, although it ought not to have been so, as it was merely a realisation of what had been anticipated by theory. The framework was held as firmly as possible by one person with his two hands, keeping it as steady as he could. The spinning by means of a fine cord[1] round a small



[1] Instead of using a long cord first wound on a bobbin, and finally wound up on the circumference of the large wheel, as described in *Nature*, February 1, 1877, p. 297, I have since found it much more convenient to use an endless cord a little more than half round the circumference of the large wheel, and less than half round the circumference of the V pulley of the gyrostat; and to keep it tight enough to exert whatever tangential force on the V pulley is desired by the person holding the framework in his hand. After continuing the spinning by turning the fly-wheel for

V pulley of $\frac{1}{2}$-inch diameter on the axis of the oval shell, and passing round a large fly-wheel of three feet diameter turned at the rate of about one round per second, was continued for several minutes. This in the case of the oblate shell, as was known from previous experiments, would have given amply sufficient rotation to the contained water to cause the apparatus to act with great firmness like a solid gyrostat. In the first experiment with the oval shell the shell was seen to be rotating with great velocity during the last minute of the spinning; but the moment it was released from the cord, and when, holding the framework in my hands, I commenced carrying it towards the horizontal glass table to test its gyrostatic quality, the framework which I held in my hands gave a violent uncontrollable lurch, and in a few seconds the shell stopped turning. I saw that one of the pivots had become bent over, by yielding of the copper shell in the neighbourhood of the stiff pivot-carrying disk, soldered to it, showing that the liquid had exerted a very strong couple against its containing shell, in a plane through the axis, the effort to resist which by my hands had bent the pivot. The shell was refitted with more strongly attached pivots, and the experiment has been repeated several times. In every case a decided uneasiness of the framework is perceived by the person holding it in his hands during the spinning; and as soon as the cord is cut and the person holding it carries it towards the experimental table, the framework begins, as it were, to wriggle round in his hands, and by the time the framework is placed on the table the rotation is nearly all gone. Its utter failure as a gyrostat is precisely what was expected from the theory, and presents a truly wonderful contrast to what is observed with the apparatus and operations in every respect similar, except having an oblate instead of a prolate shell to contain the liquid.

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8. *On a Disturbing Infinity in Lord Rayleigh's Solution for Waves in a Plane Vortex Stratum. By* Professor Sir WILLIAM THOMSON, *M.A., F.R.S.*

Lord Rayleigh's solution involves a formula equivalent to

$$\frac{d^2 v}{dy^2} - \left(m^2 + \frac{\frac{d^2 T}{dy^2}}{T - \frac{n}{m}} \right) v = 0.$$

Where v denotes the maximum value of the y-component of velocity;

„ m „ a constant such that $\frac{2\pi}{m}$ is the wave-length;

„ T „ the translational velocity of the vortex-stratum when undisturbed, which is in the x-direction, and is a function of y;

„ n „ the vibrational speed, or a constant such that $\frac{2\pi}{n}$ is the period.

Now a vortex stratum is stable, if on one side it is bounded by a fixed plane, and if the vorticity $\left(\text{or value of } \frac{dT}{dy}\right)$ diminishes as we travel (ideally) from this plane, except in places (if any) where it is constant.

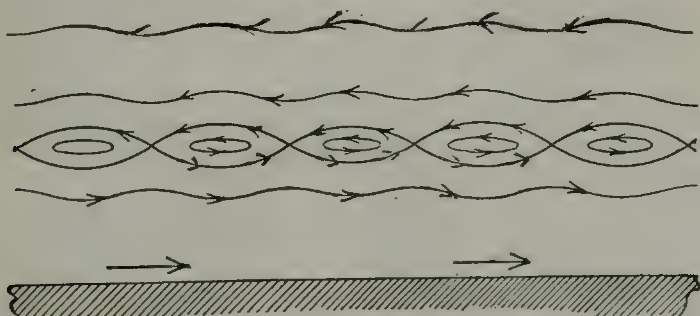
To fulfil this condition, suppose a fixed bounding plane to contain ox and be perpendicular to oy; and let $\frac{dT}{dy}$ have its greatest value when $y = o$, and decrease continuously, or by one or more abrupt changes, from this value, to zero at $y = a$ and for all greater values of y.

It is easily proved that the wave-velocity, whatever be the wave-length, is intermediate between the greatest and least values of T. Hence for a certain value of y between 0 and a, the translational velocity is equal to the wave-velocity, or

as long a time as is judged proper, the endless cord is cut with a pair of scissors and the gyrostat is released.

$T = \frac{n}{m}$. Hence for this value of y the second term within the bracket in Lord Rayleigh's formula is infinite unless, for the same value of y, $\frac{d^2 T}{d y^2}$ vanishes.

We evade entirely the consideration of this infinity if we take only the case of a layer of constant vorticity $\left(\frac{d T}{d y} = \text{constant from } y = o \text{ to } y = a\right)$, as for this case the formula is simply $\frac{d^2 v}{d y^2} = m^2 v$, but the interpretation of the infinity which occurs in the more comprehensive formula suggests an examination of the stream-lines by which its interpretation becomes obvious, and which proves that even in the case of constant vorticity the motion has a startlingly peculiar character at the place where the translational velocity is equal to the wave-velocity. This peculiarity is represented by the annexed diagram, which is most easily understood if



we imagine the translational velocities at $y = 0$ and $y = a$ to be in opposite directions, and of such magnitude that the wave-velocity is zero; so that we have the case of standing waves. For this case the stream lines are as represented in the annexed diagram, in which the region of translational velocity greater than wave-propagational velocity is separated from the region of translational velocity less than wave-propagational velocity by a cat's-eye border pattern of elliptic whirls.

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9. *Supplement to a Paper on the Synchronism of Mean Temperature and Rainfall in the Climate of London. By* H. Courtenay Fox, *M.R.C.S.*

In the Report of the British Association for 1879, page 277, is an abstract of a paper on the above subject which I had the pleasure of reading last year. The rainfall-data which I then used were of two kinds—namely, first, the monthly rainfall at the Royal Observatory back to the year 1841; and, secondly (for the years 1813 to 1840), the rainfall for every month collected by Mr. Dines from sundry observations about London. After I had presented this paper, Mr. Glaisher kindly favoured me with a table of the monthly rainfall at Greenwich, going back to the year 1815.

I have since gone carefully through my paper with it, and am glad to state that the results which I ventured to offer to the Association are, with small exception, fully confirmed.

Conclusion No. 1 is confirmed, with the exception that February loses the synchronism of cold with dry, although that of warm with wet is retained.

Conclusions Nos. 2 and 3 are confirmed.

Conclusion No. 4:—The results for April and November are unchanged. The four remaining months, though in some respects they presented 'slight' tendencies to the association of extremes of rainfall and temperature, were more or less *indefinite* in character. This is still the case as regards March, September, and October, but in May the tendency is for the synchronism of cold with wet to prevail.

TUESDAY, AUGUST 31.

The following Reports and Papers were read:—

1. *Report of the Committee for commencing Secular Experiments on the Elasticity of Wires.*—See Reports, p. 61.

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2. *On the Elasticity of Wires.*
By J. T. Bottomley, *M.A.*, *F.R.S.E.*

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3. *Report of the Committee on the Specific Inductive Capacity of a good Sprengel Vacuum.*—See Reports, p. 197.

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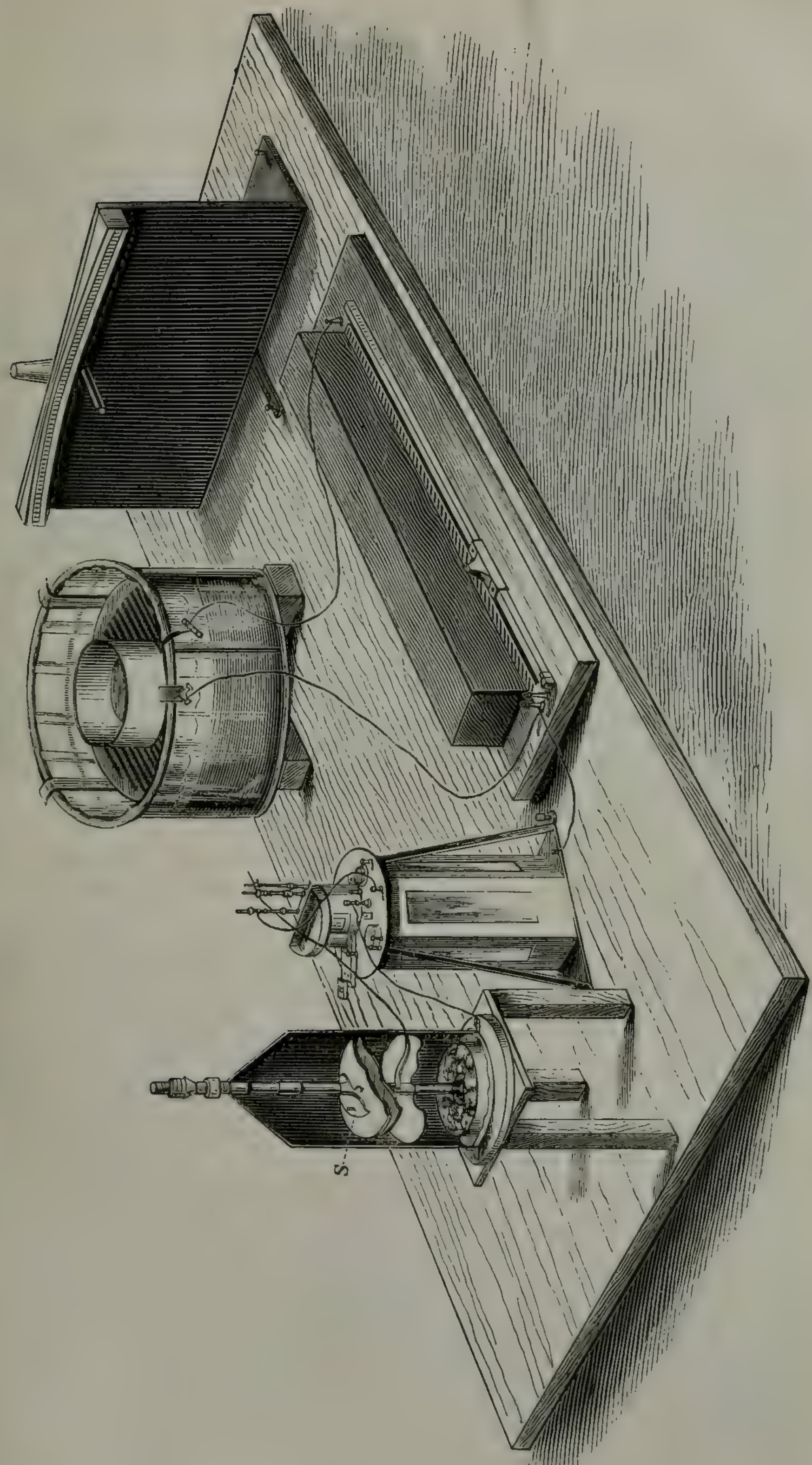
4. *On a method of measuring Contact Electricity.*
By Professor Sir William Thomson, *M.A.*, *F.R.S.*

In my reprint of Papers on 'Electrostatics and Magnetism,' section 400 (of date January 1862), I described briefly this method, in connection with a new physical principle, for exhibiting contact electricity by means of copper and zinc quadrants substituted for the uniform brass quadrants of my quadrant electrometer. I had used the same method, but with movable discs for the contact electricity, after the method of Volta, and my own quadrant electrometer substituted for the gold-leaf electroscope by which Volta himself obtained his electric indications, in an extended series of experiments which I made in the years 1859–61.

I was on the point of transmitting to the Royal Society a paper which I had written describing these experiments, and which I still have in manuscript, when I found a paper by Hankel in Poggendorff's 'Annalen' for January 1862, in which results altogether in accordance with my own were given, and I withheld my paper till I might be able not merely to describe a new method, but, if possible, add something to the available information regarding the properties of matter to be found in Hankel's paper. I have made many experiments from time to time since 1861 by the same method; but have obtained results merely confirmatory of what had been published by Pfaff in 1820 or 1821, showing the phenomena of contact electricity to be independent of the surrounding gas, and agreeing in the main with the numerical values of the contact differences of different metals which Hankel had published; and I have therefore hitherto published nothing except the slight statements regarding contact electricity which appear in my 'Electrostatics and Magnetism.' As interest has been recently revived in the subject of contact electricity, the following description of my method may possibly prove useful to experimenters. The same method has been used to very good effect, but with a Bohnenberger electroscope instead of my quadrant electrometer, in researches on contact electricity by Monsieur H. Pellat, described in the 'Journal de Physique' for May 1880.

The apparatus used in these experiments was designed to secure the following conditions:—To support two circular discs of metal about four inches in diameter in such a way that the opposing surfaces should be exactly parallel to each other and approximately horizontal; and that the distance between them might be varied at pleasure from a shortest distance of about $\frac{1}{50}$ of an inch to about a quarter or half an inch. The lower plate, which was the insulated one, was fixed in a glass stem rising from the centre of a cast-iron sole plate. The upper plate was suspended by a chain to the lower end of a brass rod sliding through a steadying socket in the upper part of the case. A stout brass flange fixed to the lower end of this rod bears three screws, one of which, S, is shown in the drawing, by which the upper plate can be adjusted to parallelism to the lower plate. The other apparatus used consisted of a quadrant electrometer and a gravity Daniell's cell of the form which I described in 'Proc. R. S.' 1871 (pp. 253–259) with a divider by which any integral number of per cents. from 0 to 100 of the electromotive force of the cell could be established between any two mutually insulated homogeneous metals in the apparatus.


S

I had a smaller apparatus, with Volta discs of only about half an inch diameter, and with gas-tight enclosing case, constructed in the year 1871; and I have made many experiments with it, of which I hope soon to publish an account.

Connections.

The insulated plate was connected by a stiff brass wire passing through a wide enough hole in the case of the Volta condenser to the electrode of the insulated pair of quadrants. The upper plate was connected to the metal case of the Volta condenser and to the metal case of the electrometer, one pair of quadrants of which were also connected to the case. One of the terminals of the divider, which connected the poles of the cell through a graduated resistance coil, was connected to the case of the electrometer, and to the other terminal was attached one of the contact wires, which was a length of insulated copper wire having soldered to its outer end a short piece of platinum. The other contact piece was a similar short piece of platinum fixed to the insulated electrode of the electrometer. Hence it will be seen that metallic communication between the two plates was effected by putting the divider at zero and bringing into contact the two pieces of platinum wire.

Order of Experiment.

The sliding piece of the divider was put to zero, and contact made and broken and the upper plate raised, and the deflection of the spot of light was observed. These operations were repeated with the sliding piece at different numbers on the divider scale until one was found at which the make-break and separation caused no perceptible deflection. The number thus found on the divider scale was the number of hundredths of the electro-motive force of the cell, which was equal to the contact electric difference of the discs in the Volta condenser.

[*Addendum*, November 23, 1880.—Since the communication of this paper to the British Association, I have found that a dry platinum disc, kept for some time in dry hydrogen gas, and then put into its position in dry atmospheric air in the apparatus for contact electricity, becomes positive to another platinum disc which had not been so treated, but had simply been left undisturbed in the apparatus. The positive quality thus produced by the hydrogen diminishes gradually, and becomes insensible after two or three days.]

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5. *On a method of determining without mechanism the limiting Steam-Liquid Temperature of a Fluid. By* Professor Sir WILLIAM THOMSON, *M.A., F.R.S.*

A piece of straight glass tube—60 centimètres is a convenient length—is to be filled with the substance in a state of the greatest purity possible. It is to contain such a quantity of the substance that, at ordinary atmospheric temperatures, about 3 or 4 centimètres of the tube are occupied by steam of the substance, and the remainder liquid. Fix the tube in an upright position, with convenient appliances for warming the upper 10 centimètres of the length to the critical temperature, or to whatever higher or lower temperature may be desired; and for warming a length of 40 centimètres from the bottom to some lower temperature, and varying its temperature conveniently at pleasure.

Commence by warming the upper part until the surface of separation of liquid and steam sinks below 5 centimètres from the top. Then warm the lowest part until the surface rises again to a convenient position. Operate thus, keeping the surface of separation of liquid and solid at as nearly as possible a constant position of 3 centimètres below the top of the tube, until the surface of separation disappears.

The temperature of the tube at the place where the surface of separation was seen immediately before disappearance is the critical temperature.

It may be remarked that the changes of bulk produced by the screw and mercury in Andrews' apparatus are, in the method now described, produced by elevations and depressions of temperature in the lower thermal vessel. By proper arrangements these elevations and depressions of temperature may be made as easily, and in some cases as rapidly, as by the turning of a screw. The dispensing with all mechanism and joints, and the simplicity afforded by using the substance to be ex-

perimented upon, and no other substance in contact with it, in a hermetically sealed glass vessel are advantages in the method now described. It is also interesting to remark that in this method we have continuity through the fluid itself all at one equal pressure exceeding the critical pressure, but at different temperatures in different parts, varying continuously from something above the critical temperature at the top of the tube to a temperature below the critical temperature in the lower part of the tube.

The pressure may actually be measured by a proper appliance on the outside of the lower part of the tube to measure its augmentation of volume under applied pressure. If this is to be done, the lower thermal vessel must be applied, not round the bottom of the tube, but round the middle portion of it, leaving, as already described, 10 or 20 cms. above for observation of the surface of separation between liquid and vapour, and leaving at the bottom of the tube 20 or 30 cms. for the pressure-measuring appliance.

This appliance would be on the same general principle as that adopted by Professor Tait in his tests of the *Challenger* thermometers under great pressure ('Proceedings Royal Soc. Edin.,' 1880); a principle which I have myself used in a form of depth-gauge for deep-sea soundings; in which the pressure is measured, not by the compression of air, but by the flexure or other strain produced in brass or glass or other elastic solid.

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6. *On the possibility of originating Wave-disturbances in the Ether by Electro-magnetic Forces. By* G. F. FITZGERALD.

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7. *On the Number of Electrostatic Units in the Electro-magnetic Unit. By* R. SHIDA, *M.E., Imperial College of Engineering, Tokio, Japan.*

The object of this paper is to explain measurements made during the month of July last for an evaluation of '*v*,' the number of electrostatic units in the electro-magnetic unit—a question which has much engaged the attention of the British Association. We can evaluate '*v*' by determining the electrostatic and also the electro-magnetic measure of any one of the following terms: Electro-motive Force, Resistance, Current, Quantity and Capacity. It is the first of these terms that I measured in the two systems of units, and the E. M. F. was that of Sir Wm. Thomson's gravity Daniell, which is very constant. The question divides itself into two parts.

(A). Absolute electrostatic measurement of the E. M. F.

This measurement was made by means of Sir Wm. Thomson's Absolute Electrometer, the most perfect instrument of the kind hitherto invented. As the description and principle of this instrument will be found fully given in Sir Wm. Thomson's 'Electrostatics and Magnetism,' I need not enter into these explanations. I may mention, however, that the instrument, perfect as it is, will not give accurate results unless considerable care be taken in using it.

In measuring an E. M. F. by this instrument, it is important that the potential of the jar or the guard ring or disc should be kept constant during the experiment. It was observed, however, that the jar was losing its charge, though very slowly, on account of the pieces of ebonite in the replenisher insulating imperfectly. Of course I could keep the potential of the jar the same during the experiment by means of the replenisher; but I found it very difficult to work the replenisher, and to take at the same time accurate readings. For this reason I thought it better, when the experiment is done by one experimenter, (or even when, I venture to think, there are more experimenters than one) to proceed in the following manner. First, connect one pole, say zinc, to the continuous plate, and the other pole to the outside of the jar, and take a reading; then reverse the poles and take another reading. Repeat the same operation—that is to say, take a great number of readings by successive reversals. If the experimenter be well practised, the time each reading will take him will be very nearly the same. Let D_1, D_2, D_3, &c., be the readings

corresponding to zinc, and D'_1, D'_2, D'_3, &c. be those corresponding to copper, then the difference of the two readings of zinc and copper would be the difference between the mean of any consecutive readings of one pole and the reading of the other taken between those two consecutive readings, such, for example, as $\frac{D_1 + D_2}{2} - D'_1$, or $\frac{D'_1 + D'_2}{2} - D_2$, &c. Thus we get many values very nearly the same, if not exactly the same, of the true difference in question; if, therefore, we take the mean of all these, the error due not only to a small loss of charge, but also to a little inaccuracy in the readings, will be avoided. This is the method I used in measuring the E. M. F. of 30 Daniell cells, and the result I obtained is the mean defined as above = 13·283 divisions of the micrometer screw-head. As regards the mathematical calculation we have

$$V - V' = 2(D - D')\sqrt{\frac{F}{R_1^2 + R_2^2}}$$

where $V - V'$ is the E. M. F. of the battery, $D - D^1$ the difference of the distances corresponding to the readings of the two poles, F the attracting force of the continuous plate on the disc, R_1 the radius of the disc, and R_2 that of the aperture. Since, now, one division of the micrometer screw-head corresponds to a distance of $\frac{5·08}{10,000}$ c.m. we get, $V - V' = ·904187$ (C. G. S.)

The E. M. F. of Thomson's gravity Daniell was measured by comparing it before and after the above experiment directly with that of the above battery by means of Sir Wm. Thomson's Quadrant Electrometer. The E. M. F. e of the cell was

$$e = \frac{V - V'}{26·299} = 0·034381 \text{ (C. G. S.) electrostatic units.}$$

(B). Absolute electro-magnetic measurement of the E. M. F.

This measurement was made by determining the strength of the current given by the E. M. F. by means of a tangent galvanometer, and then measuring the resistance of the circuit in the way to be described presently.

The tangent galvanometer employed consists of a circular coil of mean radius 18·2 c.m., containing 400 turns in 19 layers of insulated copper wire, the breadth and the depth of the coil being 2 and 1·3 c.m. respectively. The needle of the galvanometer consists of a magnet only about ½ c.m. long, made of hard tempered steel wire, and suspended in the centre of the coil by a single silk fibre. To the needle is attached a very fine straight glass fibre, of such a length that its ends travel round a graduated dial of radius a little less than that of the coil, thus serving for taking readings.

The mathematical theory shows that in a tangent galvanometer,

$$c = \frac{H\sqrt{r_0^2 + b^2}\tan a}{2\pi n} \quad \frac{3q^2r_0^2}{3q^2r_0^2 \times d^2(q^2 - 1)} \ldots\ldots (1);$$

where c is the current strength, H the horizon comp. of earth magnetism, a the angle of deflection, n the number of turns of wire in the coil, r_0 the mean radius of the coil, b half the breadth of the coil in the plane at right angles to the plane of the coil, d half the depth of the coil in its plane, q the number of layers in the coil. If E be the E. M. F. producing the current c in a circuit of resistance R, then by Ohm's law and from the preceding equation we get

$$E = \frac{RH\sqrt{r_0^2 + b^2}\tan a}{2\pi n} \cdot \frac{3q^2r_0^2}{3q^2r_0^2 + d^2(q^2 - 1)} \ldots\ldots (2).$$

The formula (2) shows that in order to measure an E. M. F. in absolute electro-magnetic units we have to determine, (a) the deflection a, (b) the resistance R, and (c) the horizontal component of earth-magnetism H.

(a) To determine a. The formula (2) also shows that whatever be the value of R the product R tan a is a constant quantity as long as E is kept constant, which furnishes this important suggestion that by varying the resistance R we

vary a and thus get many values, very nearly equal, if not equal, of the product R tan a, the mean of which would be the more accurate value of the product. The determination of a therefore was performed as follows. The current from the gravity cell was passed through the tangent galvanometer g and a variable resistance r, and the deflection a was noted. The object of introducing the variable resistance is (1) to enable us to alter the resistance R, and (2) to obtain the deflection giving minimum error, which is 45°.

(b) To determine R ($= g + b + r$). The resistance g of the galvanometer was measured by Wheatstone's bridge-method, and was equal to 30·86 ohms. The resistance b of the battery was measured by measuring the deflections produced on the scale of Sir Wm. Thomson's Quadrant Electrometer by connecting the electrodes of the cell to those of the electrometer—first when the cell was unshunted; and, secondly, when it was shunted by a known resistance; the resistance b in this case is equal to the product of the difference of the two readings into the shunt divided by the second reading. It was exactly equal to 2·02 ohms. So that we have

a	r	R	
45° – 15′	80 ohms	107·88	
42° – 45′	100 „	112·88	∴ the mean value of R tan a = 104·73 × 10⁹.
51° – 39′	50 „	82·88	

It must, however, be remembered that in all these measurements the ohm, or B.A. unit of resistance, is assumed to be exactly 10^9 C. G. S. units, which is unfortunately doubtful, as was well remarked by Professor Adams, the President of this Section, in his address.

(c) To determine H. The method of determining this element consisted in (1) observing the period of vibration of a magnet under H; and (2), observing the deflection of a magnetometer placed in the magnetic meridian by the action of the magnet placed at a fixed distance in a line at right angles to the magnetic meridian and passing through the centre of the magnetometer. I made the experiment with two different magnets made out of very hard tempered steel wire about 0·97 c.m. in diameter, and also experimented with each magnet by varying the distance of the magnet, and found the results to agree very closely with one another. The mean value of H obtained with one magnet is ·15955, and the mean value obtained with the other is ·15937, so that the mean of these two is

$$H = \cdot 15947$$

The formula used in the calculation of H is

$$H = \frac{2\pi}{t(k-l)(k+l)}\sqrt{\frac{2ki}{\tan\phi}}.$$

where t is period of vibration of magnet under H; k distance of the centre of the magnet from the magnetometer; l half the length of magnet; i the moment of inertia of the magnet; ϕ the angle of deflection of the magnetometer.

We have now come to the evaluation of 'v.' The formula (II.) gives

$$\epsilon = 1\cdot 01172 \times 10^8 \text{ (C. G. S.) electro-magnetic units.}$$

Hence

$$v = 294\cdot 4 \times 10^8 \text{ centimètres per second,}$$

which agrees well with the latest value obtained by Sir Wm. Thomson, namely, $293 \cdot \times 10^8$.

Although I took as much care as possible in making all the above measurements leading to this evaluation of 'v,' yet since, from want of time, it was only on one occasion that I was able to make the complete measurements, there may have been some cause or causes of error unnoticed. I intend, therefore, to repeat the whole experiment, and hope to be able to make a further communication.

In conclusion, I must say—and I say with extreme gratitude—that if the experiment be in any way satisfactory, it is chiefly due to the very able and kind instructions given me by Sir Wm. Thomson and his assistants in carrying out the experiment.

8. *On an Electro-magnetic Gyroscope. By* W. DE FONVIELLE.

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9. *Sur les Transformations successives desImag es photographiques, et les Applications à l'Astronomie. Par* M. J. JANSSEN, *de l'Institut, Directeur de l'Observatoire de Meudon.*

Les études que je poursuis à Meudon sur l'application de la photographie à l'étude de la constitution du soleil, m'ont conduit à étendre nos connaissances sur les transformations de l'image photographique par l'action seule de la lumière.

On avait déjà reconnu depuis longtemps que l'image photographique pouvait être renversée, soit par l'effet de certains réactifs, soit par l'action simultanée ou successive de lumières de réfrangibilité différentes. MM. Draper, C^e Abney, Vogel, notamment ont accompli, dans cette direction, de remarquables travaux. Tout dernièrement on reconnut en Allemagne que la seule prolongation d'action de la lumière pouvait amener l'inversion de l'image pour des plaques au gélatino-bromure ou au tannin.

De notre côté, à Meudon, nous obtenions, en juin dernier, des images positives du soleil sur plaques au gélatino-bromure, au tannin, etc., par la seule action prolongée de la lumière même qui donne l'image. Mais bientôt ce premier résultat fut complété, et nous avons été conduit à reconnaître que la seule action prolongée, ou suffisamment intense, de la lumière, amène six phases successives et bien distinctes dans l'état de la plaque photographique.

1° La phase de négativité, c'est la phase de l'image ordinaire.

2° La première phase de neutralité. Dans cette phase, l'image négative a disparu; la plaque est presque uniformément obscure.

3° La phase de positivité. Pendant cette phase, l'image négative a été remplacée par une image exactement inverse, c'est-à-dire positive. Cette phase est beaucoup plus longue que la phase négative qui précède.

4° À cette phase succède une nouvelle phase de neutralité, mais qui diffère de la première en ce que la plaque devient ici uniformément claire au développement, au lieu d'être obscure.

5° L'action lumineuse continuant, une nouvelle image négative apparaît, image que nous nommons du second ordre, pour la distinguer de la première image négative qui s'est formée sur la plaque. Cette phase est encore beaucoup plus longue que la positive précédente.

6° Enfin, l'action lumineuse se prolongeant toujours, cette image disparaît à son tour, et la plaque devient, après développement, presque uniformément obscure. C'est la phase d'obscurité du second ordre.

Il suit de ces résultats que l'action de la lumière sur les substances examinées est périodique; que pour une certaine durée de son action elle provoque, par le développement, un dépôt métallique; que pour une action plus longue, elle cesse de le provoquer; qu'elle le provoque de nouveau pour un temps d'action encore plus considérable, etc.

Je me propose de déterminer les rapports qui existent entre ces durées d'actions différents et si remarquables. Déjà j'ai pu constater approximativement que le temps d'action qui donne l'image négative du deuxième ordre doit être plus d'un million de fois celui qui donne celle du premier.

C'est la puissance de nos appareils de photographie céleste qui nous a permis de réaliser, dans de courtes périodes, des différences aussi considérables dans les actions lumineuses.

Nous avons obtenu, à l'observatoire de Meudon, des images positives directes du soleil de 4, 10, 30 centimètres de diamètre. Ces images directes montrent le soleil comme il est vu dans les lunettes.

Ces images sont entourées d'un cercle noir, sur la signification duquel nous aurons à revenir.

En variant convenablement le temps de l'action lumineuse par une disposition

spéciale, nous avons pu obtenir des images solaires où une partie est positive, une partie neutre-claire, une partie négative du deuxième ordre, etc.

J'ai l'honneur de joindre à cette note:

1° Une image solaire de 10 centimètres (boîte) de diamètre, positive.

2° Une image solaire de 4 centimètres de diamètre, positive.

3° Une image solaire avec partie neutre-claire.

4° Une image solaire ayant une partie positive, une neutre-claire, une négative du deuxième ordre, etc.

5° Un paysage négatif avec soleil positif dans un ciel négatif.

6° Un paysage coupé en trois parties, obtenu par contact avec un cliché négatif.

Premier tiers : négatif 1^{er} ordre.

Deuxième tiers: positif.

Troisième tiers: négatif, 2^{me} ordre (les apparences sont inverses, parce que le cliché producteur est négatif).

7° Une photographie de taches solaires obtenue d'un cliché de 30 centimètres de diamètre pour un grossissement de trois fois. Cette photographie montre les stries de la pénombre et les granulations de la surface environnante.

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10. *On Improvements in Electro-Motors.*[1] *By* THEODOR WIESENDANGER.

1. The inventors of the most recent electro-motive engines have worked—perhaps unconsciously—upon the idea, that the construction and action of electro-motors are based altogether upon the same laws as those of dynamo and magneto-machines and in accordance with that assumption the field-magnets of the Desprez-Motor are made to consist of large and heavy masses of magnetised steel.

2. Experimenters have also for a long time past clung to the idea that the efficiency of an electro-motor, or the amount of energy to be obtained from such a machine, by means of a current of given strength circulating in the coils of its armature only, bears a definite and direct proportion to the magneto-inductive power of its field-magnets, and that an increase of power in the field-magnets alone must necessarily produce greater capabilities of the machine.

3. This, however, is a mischievous theory, because erroneous in its very principles, and its development would only lead to the hypothesis of perpetual motion. On the contrary, starting from a consideration of the facts that a very small magnetic needle, if acted upon by one of the poles of another and very powerful magnet, has its polarity destroyed or reversed, and that, if one of its poles, say the N pole, is presented to a similar (N) pole of the large magnet, the former will completely lose its characteristic qualities and be attracted by its over-powering opponent, we can only come to the one rational conclusion, that the power of the field-magnets of an electro-motor, as compared with that of the magnet or magnets constituting its armature, should not surpass the limit of some certain ratio, yet to be determined by experiments carefully conducted, and that, if it surpasses that limit, the capabilities of the machine must be impaired. Acting on this principle the inventor constructed a motor (the motor was shown in motion) in which the power of the field-magnets is as nearly as possible equal to that of the armature, the core of the former being very light and made entirely of soft iron; and the satisfactory results obtained from this machine are a sure sign that a further investigation of the subject, and experiments made with a view of determining the exact ratio, will lead to further improvement. Another very important consideration in the construction of electro-motors is the method of motion of the revolving armature, with regard to the approach to, or the receding of its poles from the poles of the field magnets. The greatest amount of power will be derived from a motor if attention is paid, not merely to the one condition that the armature should revolve in the most highly concentrated magnetic

[1] Published *in extenso*, with illustrations, in the *English Mechanic*; also in *Design and Work*, September 18, 1880.

field possible, but also to the other, of no less moment, that nearly the entire motion of the revolving armature should be either one of approach to or of withdrawal from the poles of the field-magnets. [Various methods of accomplishing this object were described and illustrated by drawing models.] Electromotive engines with field-magnets of more than two poles are more perfect in their action than others with field-magnets of two poles only, mainly because in the former the line of attraction, as exercised between the two systems of poles is at angles varying from 80 to 1 degrees from the motion of the poles of the armature, while in the latter the line of attraction very nearly coincides with the line of motion. The relative positions to each other of the axes of the systems of field-magnets and the magnets constituting the armature, and the ratio of power of the two systems, are both matters awaiting careful investigation from men of science, and further researches in this most important and interesting field of work must lead to immediate progress. With regard to the former question we have as yet only the vague, unsatisfactory hypothesis of 'lines of force,' and the latter point appears to have escaped altogether the notice of both inventors and investigators.

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11. *On a New Mode of Illuminating Microscopic Objects.* *By* Philip Braham, *F.C.S.*

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12. *On an Instrument for the Detection of Polarised Light.* *By* Philip Braham, *F.C.S.*

Section B.—CHEMICAL SCIENCE.

President of the Section—Joseph Henry Gilbert, Ph.D., F.R.S., F.C.S., F.L.S.

[For Dr. Gilbert's Address see page 507.]

THURSDAY, AUGUST 26.

The following Reports and Papers were read:—

1. *Report of the Committee on the Best Means for the Development of Light from Coal Gas of different qualities. Part II.*—See Reports, p. 241.

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2. *On some Relations between the Atomic Volumes of Certain Elements and the Heats of Formation of some of their Compounds. By* Walter Weldon, *F.R.S.E.*

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3. *On the Influence of Water on the Union of Carbonic Oxide with Oxygen at High Temperatures. By* Harold B. Dixon, *M.A., F.C.S.*

When a spark from a Leyden jar is passed through a mixture of two volumes of carbonic oxide and one volume of oxygen, which has been thoroughly dried, no explosion is caused. It is very difficult to dry the gases thoroughly enough to prevent the explosion under atmospheric pressure; but by a reduction of pressure it is easy to show that a mixture of dry gases will not explode under the influence of the spark, which mixture readily explodes on addition of a minute trace of moisture. It was found that, when the pressure in a dried eudiometer was gradually increased until the passage of the spark caused the gases to combine, the disc of flame passed quite slowly down the tube, whereas when the tube was saturated with moisture the flame travelled too quickly to be followed by the eye. Some of the mixture sealed up in a glass tube with anhydrous phosphoric acid under atmospheric pressure, would not explode on passing a succession of sparks through it. On opening the sealed end under water, the spark caused the gases to unite. Into a similar tube containing anhydrous phosphoric acid, a piece of potash was fused to the glass; when filled with the mixture and sealed up, the gases would not combine on passing the spark. On gently heating the potash with a Bunsen flame, the spark caused an explosion.

It was found that a small admixture of dry carbonic acid with the gases had no effect in determining the explosion. Neither dry nitrogen nor dry cyanogen had any effect, while the smallest admixture of hydrogen or ether vapour caused the gases to explode on passing a spark. From these experiments it appears probable that the oxidation of carbonic oxide is really caused by the alternate reduction and oxidation of water molecules, according to the equations:—

$$(1)\quad CO + H_2O = CO_2 + H_2$$
$$(2)\quad 2H_2 + O_2 = 2H_2O.$$

A *comparatively* small number of water molecules suffices to determine the explosion; but the explosion gains in intensity the greater the number of water molecules present. It was shown by experiments at 52° C. that the force of the explosion was

greater when the number of water molecules was equal to the number of carbonic oxide molecules, than when a fewer number of water molecules were present, and their place taken by molecules of nitrogen, whose specific heat is less than half that of steam.

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4. *On Metallic Compounds containing Divalent Organic Radicals. Part I.* *By* J. SAKURAI.[1]

With the view of isolating metallic combinations of olefiant gas, Wanklyn and Von Than ('Jour. Chem. Soc.' xii. 258) studied the action of mercury and zinc upon ethylene iodide; but they failed in obtaining even a trace of organometallic compounds. I repeated their experiments not only with iodide and chloride of ethylene, but also with the bromide and the chloriodide, and under various conditions; but the results obtained are essentially the same as those described by the above-named chemists. Olefiant gas is given off in abundance, and metallic chloride, bromide, or iodide is formed at the same time.

At the suggestion of Professor Williamson, methylene iodide was next tried; for it appeared probable that with this compound the decomposition into metallic iodide on the one hand, and into the hydrocarbon on the other, would be impossible, or, at any rate, would not take place under such circumstances as those which, while easily allowing the ethylene compound to decompose, are, at the same time, favourable for, or essential to, the formation of organometallic compounds.

This anticipation was realised. By leaving methylene iodide in contact with metallic mercury and some mercurous iodide for a few days, combination takes place without any evolution of gas. One point of interest in the reaction consists in the part played by the mercurous iodide. This, under the influence of light, decomposes into metallic mercury and mercuric iodide: the former enters into combination with methylene iodide; and the latter, taking up fresh mercury, reproduces mercurous iodide ready for decomposition.

Chiefly two products are formed. One of these, when properly purified, is a white crystalline substance, insoluble in water, cold alcohol, ether, chloroform, ethylic iodide, or benzene. It is somewhat soluble in boiling alcohol, from which it crystallises out, on cooling, in white slender needles. But by far the best solvent for it is methylene iodide, which, when hot, takes up a considerable quantity of the substance, and allows a part of it to crystallise out on cooling. From the mother liquor, ether precipitates it almost completely in the form of fine crystals. The substance melts at 108° to 109° C. to a clear yellow liquid, in which state it remains up to a considerably higher temperature. On cooling, it solidifies to a yellow crystalline mass, and re-melts at the original temperature.

The following numbers were obtained on analysis:—

I. 0·2075 gr. of the substance gave 0·1030 gr. of mercuric sulphide.
II. 0·0910 ,, ,, 0·0455 ,, ,,
and 0·0910 ,, silver iodide.

Thus—

	Found. I.	Found. II.	Calc. for CH_2HgI_2
Mercury . .	42·790	43·100	42·735
Iodine . . .	—	54·040	54·273

Heated with iodine, the substance is decomposed into mercuric and methylene iodide. Quantitative determinations show that for every 100 parts by weight of the substance, 54·54 parts by weight of iodine are needed; that is, as much iodine as is contained in 100 parts of the substance. Now, if the compound contains in its molecule nothing but a molecule of methylene iodide and an atom of mercury, it ought to require, as it does, for the completion of the reaction, *i.e.* for the production of methylene iodide and mercuric iodide, just as much iodine as it contains, thus:—

$$CH_2HgI_2 + I_2 = CH_2I_2 + HgI_2.$$

Bromine and chlorine act upon the body in a manner similar to that of iodine.

[1] *Journal of Chemical Society*, September 1880.

The simplest, and indeed the most reasonable, constitutional formula that can be assigned to this new body, which may be termed *monomercuric methylene iodide*, is $I(CH_2)''HgI$, the divalent radical methylene $(CH_2)''$, combining to the extent of half of its power with iodine on the one hand, and to the same extent on the other, with HgI, which plays the part of a monatomic radical. The novelty of the compound is revealed in the fact just stated, inasmuch as all the so-called organo-metallic bodies hitherto known are characterised by the monatomic nature of the alcohol radicals which they contain, viz. methyl, ethyl, amyl, and allyl.

It has already been stated that two products are formed by the action of mercury upon methylene iodide. This second compound has not yet been obtained in the pure state. It was, however, analysed; and from the results, as well as from some of its reactions, there is reason to believe that this body is *dimercuric methylene iodide*, $CH_2(HgI)_2$.

The action of zinc, as well as of sodium amalgam in presence of acetic ether, upon methylene iodide were tried, and the results of these experiments will be the subject of a future paper. If the zinc compound be successfully isolated, it cannot fail to be of great service in building up bodies of the homologous series, where the consecutive members differ by CH_2, and we may thus be able to synthesise higher alcohols by a comparatively simple process.

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5. *On the Application of Organic Acids to the Examination of Minerals. By* Professor H. CARRINGTON BOLTON, *Ph.D.*

The following research into the behaviour of the commoner minerals with organic acids was prompted by the difficulty of transporting the liquid mineral acids on mineralogical and geological journeys. A careful study of the action of citric acid on 200 mineral species has established the fact that this organic acid possesses a power of decomposing minerals only slightly less than that of hydrochloric acid.

The manner of conducting the investigation was briefly as follows: the mineral to be examined was very finely pulverised, and treated in a test-tube with a saturated solution of the organic acid in the cold, and then the contents were heated to boiling. Preference is given to citric acid, because it appears to have greater decomposing power than either tartaric or oxalic, owing probably to the greater solubility of metallic citrates.

In order to increase the power of the organic acid, two other reagents have been employed in connexion with it; these are sodium nitrate and potassium iodide. These are added, in solid form, to saturated solutions of the citric acid at the moment of using.

Minerals belonging to several groups were submitted to these processes, and gave phenomena which may be summarised as follows:—

1st. More or less complete decomposition and solution of oxides, phosphates, &c., without formation of precipitates or liberation of gases.

2nd. Complete solution of carbonates, with liberation of carbonic anhydride.

3rd. Decomposition of certain sulphides with evolution of sulphuretted hydrogen.

4th. Decomposition of certain sulphides, with oxidation of the sulphur.

5th. More or less perfect decomposition of silicates, with separation of either slimy or gelatinous silica.

6th. Decomposition of certain species by reagents forming characteristic precipitates.

7th. Wholly negative action.

The exact behaviour of each species is shown in the annexed table.

The application of this method of examining minerals to field work is obvious; and this newly developed power of organic acids has undoubtedly an important bearing on the chemistry of geological changes. The quiet work of the organic acids of the soil in decomposing rocks and minerals demands greater recognition than is usually accorded.

Table showing the behaviour of certain Minerals with Citric Acid, alone and with reagents.

By Prof. H. CARRINGTON BOLTON, Ph.D.

<table>
<tr><th colspan="8">DECOMPOSED (IN FINE POWDER) BY A SATURATED SOLUTION OF CITRIC ACID</th><th rowspan="3">I
Dissolved by boiling with $\bar{C}+NaNO_3$</th><th rowspan="3">K
Decomposed by boiling with $\bar{C}+KI$</th></tr>
<tr><th colspan="4">IN THE COLD</th><th colspan="4">ON BOILING</th></tr>
<tr><th>A
Without evolution of Gas</th><th>B
With liberation of CO_2</th><th>C
With liberation of H_2S</th><th>D
With separation of SiO_2</th><th>E
Without evolution of Gas</th><th>F
With liberation of CO_2</th><th>G
With liberation of H_2S</th><th>H
With separation of SiO_2</th></tr>
<tr>
<td>Clausthalite,
Leucopyrite,
Atacamite,
Brucite,
Gummite,
Pyromorphite,*
Mimetite,
Triphylite,
Triplite,
Vivianite,!
Libethenite,!
Olivenite,!
Pseudomalachite,
Wavellite,
Pharmacosiderite,!
Torbernite,
Autunite,
Ulexite,!
Cryptomorphite,!
Anglesite,
Brochantite.!</td>
<td>Calcite,!
Dolomite,*
Gurhofite,!
Ankerite,*
Rhodochrosite,*
Smithsonite,*
Aragonite,!
Witherite,!
Strontianite,!
Barytocalcite,!
Cerussite,!
Malachite,!
Azurite.*</td>
<td>Stibnite,
Galenite,
Alabandite,!
Sphalerite,
Pyrrhotite.</td>
<td>Wollastonite,
Rhodonite,!
Chrysolite,
Willemite,!‡
Nephelite,
Lapis lazuli,
Chondrodite
Pectolite,!‡
Laumontite,!‡
Chrysocolla,!
Calamine,!‡
Apophyllite,
Thomsonite,!
Natrolite,!‡
Mesolite,!
Analcite,
Chabasite,
Herschelite,‡
Stilbite,
Deweylite,
Prochlorite.</td>
<td>Cuprite,!
Zincite,
Melaconite,
Goethite,*
Limonite,*
Allanite,(?)
Apatite,*
Wolframite,*
Wulfenite,
Crocoite,
Gypsum,*

and those in A.</td>
<td>Hausmannite,†
Pyrolusite,!†
Manganite,†
Psilomelane,!†
Wad,!†
Magnesite,!
Siderite,!

and those in B.</td>
<td>Bornite,
Jamesonite,*
Bournonite,*
Boulangerite,
Kermesite,

and those in C.</td>
<td>Tephroite,‡
Ilvaite,
Phlogopite,*
Datolite,!‡
Prehnite,*
Heulandite,
Serpentine,
Chrysotile,
Retinalite,
Bastite,
Genthite,
Gieseckite,*
Jefferisite,
Masonite,*

and those in D.</td>
<td>Silver,
Mercury,
Copper,
Arsenic,
Antimony,
Bismuth,
Sulphur,*
Bismuthinite,
Domeykite,!
Argentite,
Hessite,
Chalcocite,!
Tiemannite,!
Millerite,!
Niccolite,!
Pyrite,!
Chalcopyrite,!
Linnaeite,
Smaltite,!
Cobaltite,!
Ullmannite,!
Marcasite,!
Arsenopyrite,!
Nagyagite,
Covellite,!
Berthierite,!
Pyrargyrite,
Tetrahedrite,!
Tennantite,!
Stephanite,
Polybasite,!
Enargite,!
Uraninite,!
Hübnerite,

and those in C and G.</td>
<td>Realgar,*
Orpiment,*
Cinnabar,!
Hematite,*
Menaccanite,*
Washingtonite,*
Magnetite,*
Franklinite,
Braunite,
Enstatite,
Hypersthene,
Augite,
Spodumene,*
Hornblende,*
Actinolite,*
Pargasite,*
Olivine,
Almandite,
Pyrope,
Colophonite,
Epidote,

and most of those in A, B, C, D, E, F, G, H, and I.</td>
</tr>
</table>

L. Minerals not decomposed by the above reagents.—Graphite, Molybdenite, Proustite, Fluorite, Cryolite, Corundum, Spinel, Chromite, Chrysoberyl, Cassiterite, Rutile, Quartz, Hyalite, Diopside, Petalite, Asbestus, Beryl, Zircon, Vesuvianite, Zoisite, Iolite, Biotite, Muscovite, Lepidolite, Wernerite, Leucite, Anorthite, Labradorite, Oligoclase, Albite, Orthoclase, Tourmaline, Andalusite, Fibrolite, Kyanite, Topaz, Titanite, Staurolite, Bowenite, Talc, Kaolin, Ripidolite, Columbite, Samarskite, Scheelite, Barite, Celestite, Anhydrite. (Two hundred species.)

! Completely decomposed or dissolved. * Feebly attacked. † The CO_2 evolved is derived from the Citric Acid. ‡ Gelatinizes.

N.B.—The gases evolved are examined with acetate of lead test-paper, the solutions with appropriate reagents. [illegible]

FRIDAY, AUGUST 27.

The PRESIDENT delivered the following Address:—

SOME of my predecessors in this Chair, whose duties as teachers of chemistry lead them to traverse a wide range of the subject every year, have appropriately and usefully presented to the Section a *résumé* of the then recent progress in the manifold branches of the science which have now such far-reaching ramifications. Such a course has, however, come to be of much less importance and interest of late years, since the systematic publication by the Chemical Society of abstracts of chemical papers in home and foreign journals as soon as possible after their appearance. Some, on the other hand, have confined attention to a department with which their own inquiries have more specially connected them. And, when the Council of the Association request a specialist like myself to undertake the Presidency of the Section, it is to be supposed they take it for granted that he will select for his opening address some branch of the subject with which he is known to be mainly associated.

But it seems to me that there is a special reason why I should bring the subject of Agricultural Chemistry before you on the present occasion. Not only is the application of chemistry to agriculture included in the title of this Section; but in 1837 the Committee of the Section requested the late Baron Liebig to prepare a report upon the then condition of Organic Chemistry, and it is now exactly forty years since Liebig presented to the British Association the first part of his report, which was entitled 'Organic Chemistry in its Application to Agriculture and Physiology;' and the second part was presented two years later, in 1842, under the title of 'Animal Chemistry, or Organic Chemistry in its application to Physiology and Pathology.'. Yet, so far as I am aware, no President of the Section has, from that time to the present, taken as the subject of his address the Application of Chemistry to Agriculture.

Appropriate as, for these reasons, it would seem that I, who have devoted a very large portion of the interval since the publication of Liebig's works, above referred to, to agricultural inquiries, should occupy the short time that can be devoted to such a purpose in attempting to note progress on that important subject, it will be readily understood that it would be quite impossible to condense into the limits of an hour's discourse anything approaching to an adequate account, either of the progress made during the last forty years, or of the existing condition of agricultural chemistry.

For what is agricultural chemistry? It is the chemistry of the atmosphere; the chemistry of the soil; the chemistry of vegetation; and the chemistry of animal life and growth. And but a very imperfect indication of the amount of labour which has been devoted of recent years to the investigation of these various branches of what might at first sight seem a limited subject will suffice to convince you how hopeless a task it would be to seek to do more than direct attention to a few points of special interest. Indeed, devoting to the purpose such leisure as I have been able to command, the more I have attempted to become acquainted with the vast literature which has been accumulated on the subject, the more difficulty have I felt in making a selection of illustrations which should not convey an idea of the limits, rather than of the extent, of the labour which has been expended, and of the results which have been attained, in agricultural research.

The works of Liebig to which I have referred have, as you all know, been the subject of a very great deal of controversy. Agricultural chemists, vegetable physiologists, and animal physiologists have each vehemently opposed some of the conclusions of the author, bearing upon their respective branches. But if the part which has fallen to my own lot in these discussions qualifies me at all to speak for others as well as myself, I would say that those who, having themselves carefully investigated the points in question, have the most prominently dissented from any

special views put forward in those works, will—whether they be agricultural chemists, vegetable physiologists, or animal physiologists—be the first to admit how vast has been the stimulus, and how important has been the direction, given to research in their own department, by the masterly review of then existing knowledge, and the bold, and frequently sagacious, generalisations of one of the most remarkable men of his time!

Confining attention to researches bearing upon agriculture, it will be well, before attempting to indicate either the position established by Liebig's first works, or the direction of the progress since made, to refer very briefly to the early history of the subject.

From what we now know of the composition and of the sources of the constituents of plants, it is obvious that a knowledge of the composition of the atmosphere and of water was essential to any true conception of the main features of the vegetative process; and it is of interest to observe that it was almost simultaneously with the establishment, towards the end of the last century, of definite knowledge as to the composition of the air and of water, that their mutual relations with vegetation were first pointed out. To the collective labours of Black, Scheele, Priestley, Lavoisier, Cavendish, and Watt, we owe the knowledge that common air consists chiefly of nitrogen and oxygen, with a little carbonic acid; that carbonic acid is composed of carbon and oxygen; and that water is composed of hydrogen and oxygen; whilst Priestley and Ingenhousz, Sennebier and Woodhouse, investigated the mutual relations of these bodies and vegetable growth. Priestley observed that plants possessed the faculty of purifying air vitiated by combustion or by the respiration of animals; and, he having discovered oxygen, it was found that the gaseous bubbles which Bonnet had shown to be emitted from the surface of leaves plunged in water consisted principally of that gas. Ingenhousz demonstrated that the action of light was essential to the development of these phenomena; and Sennebier proved that the oxygen emitted resulted from the decomposition of the carbonic acid taken up.

So far, however, attention seems to have been directed more prominently to the question of the influence of plants upon the media with which they were surrounded, than to that of the influence of those media in contributing to the increased substance of the plants themselves. Towards the end of the last century, and in the beginning of the present one, De Saussure followed up these inquiries; and in his work entitled, 'Recherches Chimiques sur la Végétation,' published in 1804, he may be said to have indicated, if not indeed established, some of the most important facts with which we are yet acquainted regarding the sources of the constituents stored up by the growing plant. De Saussure illustrated experimentally, and even to some extent quantitatively, the fact that in sun-light plants increase in carbon, hydrogen, and oxygen, at the expense of carbonic acid and of water; and in the case of his main experiment on the point, he found the increase in carbon, and in the elements of water, to be very closely in the proportion in which these are known to exist in the carbohydrates. He further maintained the essentialness of the mineral or ash constituents of plants; he pointed out that they must be derived from the soil; and he called attention to the probability that the incombustible constituents so derived by plants from the soil were the source of those found in the animals fed upon them.

With regard to the nitrogen which plants had already been shown to contain, Priestley and Ingenhousz thought their experiments indicated that they absorbed free nitrogen from the atmosphere; but Sennebier and Woodhouse arrived at an opposite conclusion. De Saussure, again, thought that his experiments showed rather an evolution of nitrogen at the expense of the substance of the plant than any assimilation of it from gaseous media. He further concluded that the source of the nitrogen of plants was more probably the nitrogenous compounds in the soil, and the small amount of ammonia which he demonstrated to exist in the atmosphere.

Upon the whole, De Saussure concluded that air and water contributed a much larger proportion of the dry substance of plants than did the soils in which they grew. In his view a fertile soil was one which yielded liberally to the plant

nitrogenous compounds, and the incombustible or mineral constituents; whilst the carbon, hydrogen, and oxygen, of which the greater proportion of the dry substance of the plant was made up, were at least mainly derived from the air and water.

Perhaps I ought not to omit to mention here that, each year for ten successive years, from 1802 to 1812, Sir Humphry Davy delivered a course of lectures on the 'Elements of Agricultural Chemistry,' which were first published in 1813, were finally revised by the author for the fourth edition in 1827, but have gone through several editions since. In those lectures, Sir Humphry Davy passed in review and correlated the then existing knowledge, both practical and scientific, bearing upon agriculture. He treated of the influences of heat and light; of the organisation of plants; of the difference, and the change, in the chemical composition of their different parts; of the sources, composition, and treatment of soils; of the composition of the atmosphere, and its influence on vegetation; of the composition and the action of manures; of fermentation and putrefaction; and finally of the principles involved in various recognised agricultural practices.

With the exception of these discourses of Sir Humphry Davy, the subject seems to have received comparatively little attention, nor was any important addition made to our knowledge in regard to it, during the period of about thirty years, from the date of the appearance of De Saussure's work in 1804 to that of the commencement of Boussingault's investigations.[1]

About 1834, Boussingault became, by marriage, joint proprietor with his brother-in-law of the estate of Bechelbronn, in Alsace. His brother-in-law, M. Lebel, was both a chemical manufacturer and an intelligent practical farmer, accustomed to use the balance for the weighing of manures, crops, and cattle. Boussingault seems to have applied himself at once to chemico-agricultural research; and it was under these conditions of the association of 'practice with science' that the first laboratory on a farm was established.

From this time forward, Boussingault generally spent about half the year in Paris, and the other half in Alsace; and he has continued his scientific labours, sometimes in the city, and sometimes in the country, up to the present time. His first important contribution to agricultural chemistry was made in 1836, when he published a paper on the amount of nitrogen in different foods, and on the equivalence of the foods, founded on the amounts of nitrogen they contained; and he compared the results so arrived at with the estimates of others founded on actual experience. Although his conclusions on the subject have doubtless undergone modification since that time, the work itself marked a great advance on previously existing knowledge, and modes of viewing the question.

In 1837, Boussingault published papers—on the amount of gluten in different kinds of wheat; on the influence of the clearing of forests on the diminution of the flow of rivers; and on the meteorological influences affecting the culture of the vine. In 1838 he published the results of an elaborate research on the principles underlying the value of a rotation of crops. He determined by analysis the composition, both organic and inorganic, of the manures applied to the land, and of the crops harvested. In his treatment of the subject he evinced a clear perception of the most important problems involved in such an inquiry; some of which, with the united labours of himself and many other workers, have scarcely yet received an undisputed solution.

Thus, in the same year (1838), he published the results of an investigation on the question whether plants assimilate the free or uncombined nitrogen of the atmosphere; and although the analytical methods of the day were inadequate to the decisive settlement of the point, his conclusions were in the main those which much subsequent work of his own, and much of others also, has served to confirm.

As a further element of the question of the chemical statistics of a rotation of crops, Boussingault determined the amount and composition of the residues of various crops; also the amount of constituents consumed in the food of a cow and

[1] Some reference should have been made in the text to the labours and writings of Dr. Carl Sprengel, late Professor of Agriculture at Brunswick, who made numerous analyses of agricultural materials, and published numerous papers in connection with Agricultural Chemistry, during a series of years, commencing about 1826.

of a horse respectively, and yielded in the milk and excretions of the cow, and in the excretions of the horse. Here, again, the exigencies of the investigation he undertook were beyond the reach of the known methods of the time. Indeed, rude as the art of agriculture is generally considered to be, the scientific elucidation of its practices requires the most refined, and very varied, methods of research; and a characteristic of the work of Boussingault may be said to be, that he has frequently had to devise methods suitable to his purpose, before he could grapple with the problems before him.

In 1839, chiefly in recognition of his important contributions to agricultural chemistry, Boussingault was elected a member of the Institute; and in 1878, thirty-nine years later, the Council of the Royal Society awarded to him the Copley Medal, the highest honour at their disposal, for his numerous and varied contributions to science, but especially for those relating to agriculture.

The foregoing brief historical sketch is sufficient to indicate, though but in broad outline, the range of existing knowledge on the subject of agricultural chemistry prior to the appearance of Liebig's memorable work in 1840. It will be seen that some very important and indeed fundamental facts had already been established in regard to vegetation, and that Boussingault had not only extended inquiry on that subject, but he had brought his own and previous results to bear upon the elucidation of long-recognised agricultural practices. There can be no doubt that the data supplied by his researches contributed important elements to the basis of established facts upon which Liebig founded his brilliant generalisations. Accordingly, in 1841, Dumas and Boussingault published, jointly, an essay which afterwards appeared in English under the title of 'The Chemical and Physiological Balance of Organic Nature;' and, in 1843, Boussingault published a larger work, which embodied the results of many of his own previous original investigations.

But there can be no doubt that the appearance of Liebig's two works, which were contributions made in answer to a request submitted to him by the committee of this Section of the British Association, constituted a very marked epoch in the history of the progress of agricultural chemistry. In the treatment of his subject he not only called to his aid the previously existing knowledge directly bearing upon it, but he also turned to good account the more recent triumphs of organic chemistry, many of which had been won in his own laboratory. Further, a marked feature of his expositions was the adoption of what may be called the *statistical* method—I use the word statistical rather than quantitative, as the latter expression has its own technical meaning among chemists, which is not precisely what I wish to convey.

It seems that, notwithstanding the conclusive evidence afforded by the direct experiments of De Saussure and his predecessors, vegetable physiologists continued to hold the view that the humus of the soil was the source of the carbon of vegetation. Not only did Liebig give full weight to the evidence of the experiments of De Saussure and others, and illustrate the possible or probable transformations within the plant by facts already established in organic chemistry, but he demonstrated the utter impossibility of humus supplying the amount of carbon assimilated over a given area. He pointed out that humus itself was the product of previous vegetable growth, and that it could not therefore be an original source of carbon; and that, from the degree of its insolubility, either in pure water or in water containing alkaline or earthy bases, only a small portion of the carbon assimilated by plants could be derived from the amount of humus that could possibly enter the plant in solution. He maintained that, so far as humus was beneficial to vegetation at all, it was only by its oxidation, and a consequent supply of carbonic acid within the soil; a source which he considered only of importance in the early stages of the life of a plant, and before it had developed and exposed a sufficient amount of green surface to the atmosphere to render it independent of soil supplies of carbonic acid.

With regard to the hydrogen of plants, at any rate that portion of it contained in their non-nitrogenous products, he maintained that its source must be water; and that the source of the oxygen was either that contained in carbonic acid or that in water.

With regard to the nitrogen of vegetation, both from the known characters of free nitrogen, and as he considered a legitimate deduction from direct experiments, he argued that plants did not take up free or uncombined nitrogen, either from the atmosphere, or dissolved in water and so absorbed by the roots. The source of the nitrogen of vegetation was, he maintained, ammonia; the product of the putrefaction of one generation of plants and animals affording a supply for its successors. He pointed out that, in the case of a farm receiving nothing from external sources, and selling off certain products, the amount of nitrogen in the manure derived by the consumption of some of the vegetable produce on the farm itself, together with that due to the refuse of the crops, must always be less than was contained in the crops grown; and he concluded that though the quantity so returned to the land was important, a main source of the nitrogen assimilated over a given area was that brought down from the atmosphere in rain.

There can be no doubt that, owing to the limited and defective experimental evidence then at command on the point, Liebig at that time (as he has since) greatly over-estimated the amount of ammonia available to vegetation from that source. In Boussingault's *réclamation* already referred to, he gave much more prominence to the importance of the nitrogen of manures. In Liebig's next edition (in 1843) he combated the notion of the relative importance of the nitrogen of manures; maintained, in opposition to the view put forward in his former edition, that the atmosphere afforded a sufficient supply of nitrogen for cultivated as well as for uncultivated plants; that the supply was sufficient for the cereals as well as for leguminous plants; that it was not necessary to supply nitrogen to the former; and he insisted very much more strongly than formerly on the relative importance of the supply of the incombustible, or, as he designated them, the 'inorganic' or 'mineral,' constituents.

As to the incombustible or mineral constituents themselves, Liebig adduced many illustrations in proof of their essentialness. He called attention to the variation in the composition of the ash of plants grown on different soils; and he assumed a greater degree of mutual replaceability of one base by another, or of one acid by another, than could be now admitted. He traced the difference in the mineral composition of different soils to that of the rocks which had been their source; and he seems to have been led by the consideration of the gradual action of '*weathering*,' in rendering available the otherwise locked-up stores, to attribute the benefits of fallow exclusively to the increased supply of the incombustible constituents which would, by its agency, be brought into a condition in which they could be taken up by plants.

The benefits of an alternation of crops Liebig considered to be in part explained by the influence of the excreted matters from one description of crop upon the growth of another. He did not attach weight to the assumption that such matters would be directly injurious to the same description of crop; but he supposed rather that the matters excreted were those which the plant did not need, and would therefore be of no avail to the same description of plant, but would be of use to another. He, however, attributed much of the benefits of a rotation to different mineral constituents being required from the soil by the respective crops.

Treating of manure, he laid the greatest stress on the return by it of the potass and the phosphates removed by the crops. But he also insisted on the importance of the nitrogen, especially that in the liquid excretions of animals, and condemned the methods of treatment of animal manures by which the ammonia was allowed to be lost by evaporation. It is curious and significant, however, that some of the passages in his first edition, in which he the most forcibly urges the value of the nitrogen of animal manures, are omitted in the third and fourth editions.

The discussion of the processes of fermentation, decay, and putrefaction, and that of poisons, contagions, and miasms, constituted a remarkable and important part of Liebig's first report. It was the portion relating to poisons, contagions, and miasms that he presented to this Section as an instalment, at the meeting of the Association held at Glasgow in 1840. It was in the chapters relating to the several subjects here enumerated that he developed so prominently his views on the influence of contact in inducing chemical changes. He cited many known

transformations, other than those coming under either of the heads in question, in illustration of his subject; and he discussed with great clearness the different conditions occurring, and the different results obtained, in various processes—such as the different modes of fermenting beer, the fermentation of wine from different kinds of grapes, the production of acetic acid, &c. As is well known, he claimed a purely chemical explanation for the phenomena involved in fermentation. He further maintained that the action of contagions was precisely similar. In his latest writings on the subject (in 1870), he admits some change of view; but it is by no means easy to decide exactly how much or how little of modification he would wish to imply.

Liebig's second report, presented at the meeting of this Association in 1842, and published under the title of 'Animal Chemistry, or Organic Chemistry in its applications to Physiology and Pathology,' perhaps excited even more attention than his first, and, probably from the manner as much as from the matter, aroused a great deal of controversy, especially among physiologists and physicians. Liebig was severe upon what he considered to be a too exclusive attention to morphological characters in physiological research, and at any rate too little attention to chemical phenomena, and, so far as these were investigated, an inadequate treatment of the subject according to strictly quantitative methods.

He combated the view that nervous action, as such, could be a source of any of the heat of the body; and he adduced numerous illustrations and calculations in support of the view that the combustion of carbon and hydrogen in the system was sufficient to account for, and was the only source of, animal heat.

He compared and contrasted the general composition of plants and animals. In accordance with Mulder, he pointed out that whilst plants formed the nitrogenous bodies which they contain from carbonic acid, water, and ammonia, animals did not produce them, but received them ready-formed in their vegetable food; that, in fact, the animal begins only where the plant ends. But, going beyond Mulder, and beyond what had then, or has since, been established, he maintained the identity in composition of the admittedly analogous nitrogenous compounds in plants and in the blood of animals.

Omitting the fat which the carnivora might receive in the animals they consumed, he stated the characteristic difference between the food of carnivora and herbivora to be, that the former obtained the main proportion of their respiratory material from the waste of tissue; whilst the latter obtained a large amount from starch, sugar, &c. These different conditions of life accounted for the comparative leanness of carnivora and fatness of herbivora.

He maintained that the vegetable food consumed by herbivora did not contain anything like the amount of fat which they stored up in their bodies; and he showed how nearly the composition of fat was obtained by the simple elimination of so much oxygen, or of oxygen and a little carbonic acid, from the various carbohydrates. Much less oxygen would be required to be eliminated from a quantity of fibrine, &c., containing a given amount of carbon, than from a quantity of carbohydrates containing an equal amount of carbon. The formation of fatty matter in plants was of the same kind; it was the result of a secondary action, starch being first formed from carbonic acid and water.

He concluded from the facts adduced that the food of man might be divided into the *nitrogenised* and the *non-nitrogenised* elements. The former were capable of conversion into blood, the latter incapable of such transformation. The former might be called the *plastic elements of nutrition*, the latter *elements of respiration*. From the plastic elements, the membranes and cellular tissue, the nerves and brain, cartilage, and the organic part of bones, could be formed; but the plastic substance must be received ready-made. Whilst gelatine or chondrine was derived from fibrine or albumen, fibrine or albumen could not be reproduced from gelatine or chondrine. The gelatinous tissues suffer progressive alteration under the influence of oxygen, and the materials for their re-formation must be restored from the blood. It might, however, be a question whether gelatine taken in food might not again be converted into cellular tissue, membrane, and cartilage, in the body.

At that time, adopting and attaching great importance to Mulder's views in

regard to proteine, he says:—'All the organic nitrogenised constituents of the body, how different soever they may be in composition, are derived from proteine. They are formed from it by the addition or subtraction of the elements of water or of oxygen, and by resolution into two or more compounds.'

He seeks to trace the changes occurring in the conversion of the constituents of food into blood, of those of blood into the various tissues, and of these into the secretions and excretions.

He states that the process of chymification takes place in virtue of a purely chemical action, exactly similar to those processes of decomposition or transformation which are known as putrefaction, fermentation, or decay. Thus, the clear gastric juice contains a substance in a state of transformation, by the contact of which with the insoluble constituents of the food they are rendered soluble, no other element taking any share in the action excepting oxygen and the elements of water. All substances which can arrest the phenomena of fermentation and putrefaction in liquids, also arrest digestion when taken into the stomach. Putrefying blood, white of egg, flesh, and cheese produce the same effects in a solution of sugar as yeast or ferment; the explanation being, that ferment, or yeast, is nothing but vegetable fibrine, albumen, or caseine, in a state of decomposition.

Referring to the derivation of the animal tissues, he says they all contain, for a given amount of carbon, more oxygen than the nitrogenous constituents of blood. In hair and gelatinous membrane there is also an excess of nitrogen and hydrogen, and in the proportions to form ammonia. We may suppose an addition of these elements, or a subtraction of carbon, the amount of nitrogen remaining the same. The gelatinous substance is not a compound of proteine; it contains no sulphur, no phosphorus; and it contains more nitrogen, or less carbon, than proteine.

He next, as he says, attempts to develop analytically the principal metamorphoses which occur in the animal body. He adds that the results have surprised himself no less than they will others, and have excited in his own mind the same doubts as others will conceive. He nevertheless gives them, because he is convinced that the method by which they have been obtained is the only one by which we can hope to acquire an insight into the nature of organic processes.

Referring to the animal secretions, he argues that they must contain the products of the metamorphosis of the tissues. He says a starving man with severe exertion secretes more urea than the most highly fed individual in a state of rest; and he combats the idea that the nitrogen of the food can pass into urea without having previously become part of an organised tissue.

Having shown the chemical relations of bile and urine to the proteine bodies, he illustrates, by formulæ, the connection between allantoine and the constituents of the urine of animals that respire. He insists that in the herbivora the carbohydrates must take part in the formation of bile; and he calculates the number of equivalents of proteine, starch, oxygen, and water, which would yield a given number of equivalents of urea, choleic acid, ammonia, and carbonic acid. The non-nitrogenous constituents in the food of the herbivora retard the metamorphosis of the nitrogenous bodies, rendering this less rapid than in the carnivora. It may be said that proteine, starch, and oxygen give the secretions and excretions—carbonic acid by the lungs, urea and carbonate of ammonia by the kidneys, choleic acid by the liver. It is the study of the phenomena which accompany the metamorphoses of the food in the organism, the discovery of the share which the atmosphere and the elements of water take in these changes, by which we shall learn the conditions necessary for the production of a secretion or of an organised part.

He traces the possible formation of taurine from caffeine or asparagine by their assumption of oxygen and of the elements of water. And from the composition of the vegetable alkaloids he suggests the possibility of their taking a share in the formation of new, or the transformation of existing, brain and nervous matter.

Finally, in reference to these various illustrations and considerations, he says, however hypothetical they may appear, they deserve attention in so far as they point out the way which chemistry must pursue if she would really be of service to physiology and pathology. Chemistry, he says, relates to the conversion of food

into the various tissues and secretions, and to their subsequent metamorphosis into lifeless compounds.

After this lapse of time, it will certainly be granted that, quite irrespectively of the admissibility or otherwise of the particular illustrations adduced, or of the truth or error of any of the conclusions drawn—and some at least are so true that they seem to us now all but truisms, and you may be disposed to ask me why I should tell you over again a story so often told before—there is no doubt that Liebig's manner of treating the subject did exert an immense influence, by stimulating investigation, by fixing attention on the points to be investigated, and on the methods that must be followed, and thus, by leading to the establishment or the correction of any special views he put forward, and to a vast extension of our knowledge on the complicated questions involved.

In the third part of Liebig's second volume he treats of the phenomena of motion in the animal organism. It is to his views in regard to one aspect only of this very wide and very complicated subject that I propose to call your attention here, as it is chiefly in so far as that aspect is concerned that the question is of interest from the point of view of the agricultural chemist. He says:—

'We observe in animals that the conversion of food into blood, and the contact of the blood with the living tissues, are determined by a mechanical force, whose manifestation proceeds from distinct organs, and is effected by a distinct system of organs, possessing the property of communicating and extending the motion which they receive. We find the power of the animal to change its place and to produce mechanical effects by means of its limbs dependent on a second similar system of organs or apparatus.'

He points out that the motion of the animal fluids proceeds from distinct organs (as, for example, that of the blood from the heart), which do not generate the force in themselves, but receive it from other parts by means of the nerves; the limbs also receive their moving force in the same way. He adds: 'Where nerves are not found, motion does not occur.' Again:—

'As an immediate effect of the manifestation of mechanical force, we see that a part of the muscular substance loses its vital properties, its character of life; that this portion separates from the living part, and loses its capacity of growth and its power of resistance. We find that this change of properties is accompanied by the entrance of a foreign body (oxygen) into the composition of the muscular fibre. . . ; and all experience proves that this conversion of living muscular fibre into compounds destitute of vitality is accelerated or retarded according to the amount of force employed to produce motion.' He adds that a rapid transformation of muscular fibre determines a greater amount of mechanical force, and that conversely a greater amount of mechanical motion determines a more rapid change of matter.

'The change of matter, the manifestation of mechanical force, and the absorption of oxygen, are, in the animal body, so closely connected with each other that we may consider the amount of motion and the quantity of living tissue transformed as proportional to the quantity of oxygen inspired and consumed in a given time by the animal.' Again:—

'The production of heat and the change of matter are closely related to each other; but although heat can be produced in the body without any change of matter in living tissues, yet the change of matter cannot be supposed to take place without the co-operation of oxygen.'

Further, on the same point:—'The sum of force available for mechanical purposes must be equal to the sum of the vital forces of all tissues adapted to the change of matter. If, in equal times, unequal quantities of oxygen are consumed, the result is obvious in an unequal amount of heat liberated, and of mechanical force. When unequal amounts of mechanical force are expended, this determines the absorption of corresponding and unequal quantities of oxygen.'

Then, more definitely still, referring to the changes which take place coincidently with the exercise of force, and to the demands of the system for repair accordingly, he says:—

'The amount of azotised food necessary to restore the equilibrium between waste and supply is directly proportional to the amount of tissues metamorphosed. The

amount of living matter, which in the body loses the condition of life, is, in equal temperatures, directly proportional to the mechanical effects produced in a given time. The amount of tissue metamorphosed in a given time may be measured by the quantity of nitrogen in the urine. The sum of the mechanical effects produced in two individuals, in the same temperature, is proportional to the amount of nitrogen in their urine, whether the mechanical force has been employed in the voluntary or involuntary motions, whether it has been consumed by the limbs, or by the heart and other viscera.'

Thus, apparently influenced by the physiological considerations which have been adduced, and notwithstanding in some passages he seemed to recognise a connection between the total quantity of oxygen inspired and consumed and the quantity of mechanical force developed, Liebig nevertheless very prominently insisted that the amount of muscular tissue transformed—the amount of nitrogenous substance oxidated—was the measure of the force generated. He accordingly distinctly draws the conclusion that the requirement for the azotised constituents of food will be increased in proportion to the increase in the amount of force expended.

It will be obvious that the question whether in the feeding of animals for the exercise of mechanical force—that is, for their labour—the demands of the system will be proportionally the greater for an increased supply of the nitrogenous or of the non-nitrogenous constituents of food, is one of considerable interest and practical importance. To this point I shall have to refer further on.

So far, I have endeavoured to convey some idea of the state of knowledge on the subject of the chemistry of agriculture prior to the appearance of Liebig's first two works bearing upon it, and also briefly to summarise the views he then enunciated in regard to some points of chief importance. Let us next try to ascertain something of the influence of his teaching.

Confining attention to agricultural research, it may be observed that in 1843—that is, very soon after the appearance of the works in question—the Royal Agricultural Society of England first appointed a consulting chemist. At that date Dr. Lyon Playfair was elected; in 1848, Professor Way; and in 1858 Dr. Voelcker, who continues to hold the office with much advantage to that union of '*Practice with Science*' which the Society by its motto recognises as so essential to progress Also in 1843 there was established the Chemico-Agricultural Society of Scotland, which was, I believe, broken up, after it had existed between four and five years, because its able chemist, the late Professor Johnston, failed to find a remedy for the potato disease. In 1845, the Chemico-Agricultural Society of Ulster was established, and appointed as its chemist, Professor Hodges, who still ably performs the duties of the office. Lastly, the very numerous '*Agricultural Experimental Stations*' which have been established, not only in Germany, but in most Continental States, owe their origin directly to the writings, the teachings, and the influence of Liebig. The movement seems to have originated in Saxony, where Stöckhardt had already stimulated interest in the subject by his lectures and his writings. After some correspondence, in 1850–1, between the late Dr. Crucius and others on the one side, and the Government on the other, the first so-called *Agricultural Experimental Station* was established at Möchern, near Leipzig, in 1851-2. In 1877, the twenty-fifth anniversary of the foundation of that institution was celebrated at Leipzig, when an account (which has since been published) was given of the number of stations then existing, of the number of chemists engaged, and of the subjects which had been investigated. From that statistical statement we learn that in 1877 the number of stations was:—

In the various German States	74
In Austria	16
In Italy	10
In Sweden	7
In Denmark	1
In Russia	3
In Belgium	3
In Holland	2

Brought forward	116
In France	2
In Switzerland	3
In Spain	1
Total	122

Besides these 122 stations on the Continent of Europe, the United States are credited with 1, and Scotland also with 1.

Each of these stations is under the direction of a chemist, frequently with one or more assistants. One special duty of most of them is what is called manure- or seed- or feeding-stuff-control; that is, to examine or analyse, and report upon such substances in the market; and it seems to have been found the interest of dealers in these commodities to submit their proceedings to a certain degree of supervision by the chemist of the station of their district.

But agricultural research has also been a characteristic feature of these institutions. It is stated that the investigation of soils has been the prominent object at 16 of them; experiments with manures at 24; vegetable physiology at 28; animal physiology and feeding experiments at 20; vine-culture and wine-making at 13; forest-culture at 9; and milk-production at 11. Others, according to their locality, have devoted special attention to fruit-culture, olive-culture, the cultivation of moor, bog, and peat land, the production of silk, the manufacture of spirit, and other products.

Nor does this enumeration of the institutions established as the direct result of Liebig's influence, and of the subjects investigated under their auspices, complete the list either of the workers engaged, or of the work accomplished in agricultural research. To say nothing of the labours of Boussingault, which commenced some years prior to the appearance of Liebig's first work, and which are fortunately still at the service of agriculture, important contributions have been made by the late Professors Johnston and Anderson in Scotland, and in this country both by Mr. Way and Dr. Voelcker, each alike in his private capacity, and in fulfilment of his duties as Chemist to the Royal Agricultural Society of England. Nor would it be fair to Mr. Lawes (who commenced experimenting first with plants in pots, and afterwards in the field, soon after entering into possession of his property in 1834, and with whom I have myself been associated since 1843) were I to omit in this place any mention of the investigations which have been so many years in progress at Rothamsted.

So much for the machinery; but what of the results achieved by all this activity in the application of chemistry to agriculture?

As I have already intimated, and as the foregoing brief statistical statement will have convinced you must be the case, it will be utterly impossible to give, on such an occasion as this, anything approaching to an adequate review of the progress achieved. Indeed, I have to confess that the more I have looked at the subject with the hope of treating it comprehensively, the more I have been impelled to substitute a very limited plan for the much more extended scheme which I had at first hoped to be able to fill up. I propose then to confine attention to a few special points, which have either some connection with one another, or to which recent results or discussions lend some special interest.

First as to the sources and the assimilation of the carbon, the hydrogen, and the oxygen of vegetation. From the point of view of the agricultural chemist, the hydrogen and the oxygen may be left out of view. For, if the cultivator provide to the plant the conditions for the accumulation of sufficient nitrogen and carbon, he may leave it to take care of itself in the matter of hydrogen and oxygen. That the hydrogen of the carbo-hydrates is exclusively obtained from water, is, to say the least, probable; and whether part of their oxygen is derived from carbonic acid, and part from water, or the whole from either of these, will not affect his agricultural practice.

With regard to the carbon, the whole tendency of subsequent observations is to confirm the opinion put forward by De Saussure about the commencement of the century, and so forcibly insisted upon by Liebig forty years later—that the greater part, if not the whole of it, is derived from the carbonic acid of the atmosphere. Indeed, direct experiments are not wanting—those of Moll, for example—from

which it has been concluded that plants do not even utilise the carbonic acid which they may take up from the soil by their roots. However this may be, we may safely conclude that practically the whole of the carbon which it is the object of the cultivator to force the plants he grows to take up is derived from the atmosphere, in which it exists in such extremely small proportion, but nevertheless large actual, and constantly renewed amount.

Judging from the more recent researches on the point, it would seem probable that the estimate of one part of carbon, as carbonic acid, in 10,000 of air, is more probably too high than too low as an estimate of the average quantity in the ambient atmosphere of our globe. And, although this would correspond to several times more in the column of air resting over an acre of land than the vegetation of that area can annually take up, it represents an extremely small amount at any one time in contact with the growing plants, and it could only suffice on the supposition of a very rapid renewal, accomplished as the result, on the one hand of a constant return of carbonic acid to the atmosphere by combustion and the respiration of animals, and on the other of a constant interchange and equalisation among the constituents of the atmosphere.

It will convey a more definite idea of what is accomplished by vegetation in the assimilation of carbon from the atmosphere if I give, in round numbers, the results of some direct experiments made at Rothamsted, instead of making general statements merely.

In a field which has now grown wheat for thirty-seven years in succession, there are some plots to which not an ounce of carbon has been returned during the whole of that period. Yet, with purely mineral manure, an average of about 1000 pounds of carbon is annually removed from the land; and where a given amount of nitrogenous manure is employed with the mineral manure, an average of about 1500 pounds per acre per annum more is obtained; in all an average of about 2500 pounds of carbon annually assimilated over an acre of land without any return of carbonaceous manure to it.

In a field in which barley has been grown for twenty-nine years in succession, quite accordant results have been obtained. There, smaller amounts of nitrogenous manure have been employed with the mineral manure than in the experiments with wheat above cited; but the increase in the assimilation of carbon for a given amount of nitrogen supplied in the manure is greater in the case of the barley than of the wheat.

With sugar-beet, again, larger amounts of carbon have been annually accumulated without the supply of any to the soil, but under the influence of a liberal provision of both nitrogenous and mineral manure, than by either wheat or barley.

Lastly, with grass, still larger amounts of carbon have been annually accumulated, without any supply of it by manure.

Many experiments have been made, in Germany and elsewhere, to determine the amount of the different constituents taken up at different periods of the growth of various plants. But we may refer to some made at Rothamsted long ago to illustrate the rapidity with which the carbon of our crops may be withdrawn from the atmosphere.

In 1847, we carefully took samples from a growing wheat crop at different stages of its progress, commencing on June 21, and in these samples the dry matter, the mineral matter, the nitrogen, &c., were determined. On each occasion the produce of two separate eighths or sixteenths of an acre was cut and weighed, so that the data were provided to calculate the amounts of the several constituents which had been accumulated per acre at each period. The result was that, whilst during little more than five weeks from June 21, there was comparatively little increase in the amount of nitrogen accumulated over a given area, more than half the total carbon of the crop was accumulated during that period.

Numerous experiments of a somewhat similar kind, made in another season, 1856, concurred in showing that, whilst the carbon of the crop was more than doubled after the middle of June, its nitrogen increased in a much less degree over the same period.

Similar experiments were also made, in 1854 and in 1856, with beans. The

general result was that a smaller proportion of both the total nitrogen and the total carbon was accumulated by the middle or end of June than in the case of the wheat; though the actual amount of nitrogen taken up by the beans was much greater, both before and after that date. The nitrogen of this leguminous crop increased in a much greater proportion during the subsequent stages of growth than did that of the gramineous crop; but the carbon increased in a larger proportion still, three-fourths or more of the total amount of it being accumulated after the middle of June.

I should say that determinations of carbon, made in samples of soil taken from the wheat field at different periods during recent years, indicate some decline in the percentage of carbon in the soils, but not such as to lead to the supposition that the soils have contributed to the carbon of the crops. Besides the amount of carbon annually removed, there will, of course, be a further accumulation in the stubble and roots of the crops; and the reduction in the total carbon of the soil, if such have really taken place, would show that the annual oxidation within it is greater than the annual gain by the residue of the crops.

Large as is the annual accumulation of carbon from the atmosphere over a given area in the cases cited, it is obvious that the quantity must vary exceedingly with variation of climatal conditions. It is, in fact, several times as great in the case of tropical vegetation—that of the sugar-cane for example. And not only is the greater part of the assimilation accomplished within a comparatively small portion of the year (varying of course according to the region), but the action is limited to the hours of daylight, whilst during darkness there is rather loss than gain.

But it is remarkable that whilst the accumulation of carbon, the chief gain of solid material, takes place under the influence of light, cell-division, cell-multiplication, increase in the structure of the plant, in other words, what, as distinguished from assimilation, vegetable physiologists designate as *growth*, takes place, at any rate chiefly, during the night; and is accompanied, not with the taking up of carbonic acid and the yielding up of oxygen, but with the taking up of oxygen and the giving up of carbonic acid. This evolution of carbonic acid during darkness must obviously be extremely small, compared with the converse action during day-light, coincidentally with which practically the whole of the accumulation of solid substance is accomplished. But, as the product of the night action is the same as in the respiration of animals, this is distinguished by vegetable physiologists as the respiration of plants.

I suppose I shall be considered a heretic if I venture to suggest that it seems in a sense inappropriate to apply the term *growth* to that which is associated with actual loss of material, and that the term *respiration* should be applied to so secondary an action as that as the result of which carbonic acid is given off from the plant. It may, I think, be a question whether there is any advantage in thus attempting to establish a parallelism between animal and vegetable processes; rather would it seem advantageous to keep prominently in view their contrasted, or at any rate complementary characteristics, especially in the matter of the taking up of carbonic acid and the giving up of oxygen on the one hand, and the taking in of oxygen and the giving up of carbonic acid on the other.

But it is obvious that in latitudes where there is comparatively continuous daylight during the periods of vegetation, the two actions—designated respectively assimilation and growth—must go on much more simultaneously than where there is a more marked alternation of daylight and darkness. In parts of Norway and Sweden, for example, where, during the summer, there is almost continuous daylight, crops of barley are grown with only from six to eight weeks intervening from seed-time to harvest. And Professor Schübeler, of Christiania, after making observations on the subject for nearly thirty years, has recently described the characteristics of the vegetation developed under the influence of short summers with almost continuous light. He states that, after acclimatisation, many garden flowers increase in size and depth of colour; that there is a prevailing tinge of red in the plants of the fjelds; that the aroma of fruits is increased, and their colour well developed, but that they are deficient in sweetness; and that the development of essential oils in certain plants is greater than in the same plants grown in other latitudes. Indeed, he considers it to be an established fact that light bears the same relation to aroma as heat does to sweetness.

In connection with this question of the characters of growth under the influence of continuous light, compared with those developed with alternate light and darkness, the recent experiments of Dr. Siemens on the influence of electric light on vegetation are of considerable interest.

In one series of experiments, he kept one set of plants entirely in the dark, a second he exposed to electric light only, a third to daylight only, and a fourth to daylight, and afterwards to electric light from 5 to 11 P.M. Those kept in the dark acquired a pale yellow colour, and died; those exposed to electric light only, maintained a light green colour, and survived; those exposed to daylight were of a darker green colour, and were more vigorous; and, lastly, those submitted to alternate daylight and electric light, and but a few hours of darkness, showed decidedly greater vigour, and, as he says, the green of the leaf was of a dark rich hue. He concluded that daylight was twice as effective as electric light; but that, nevertheless, 'electric light was clearly sufficiently powerful to form chlorophyll and its derivatives in the plants.'

In a second series of experiments one group of plants was exposed to daylight alone; a second to electric light during eleven hours of the night, and was kept in the dark during the day; and a third to eleven hours day, and eleven hours electric light. The plants in daylight showed the usual healthy appearance; those in alternate electric light and darkness were for the most part of a lighter colour; and those in alternate daylight and electric light far surpassed the others in darkness of green and vigorous appearance generally.

I have carefully considered these general descriptions with a view to their bearing on the question whether the characters developed under the influence of electric light, and especially those under the influence of almost continuous light, are more prominently those of assimilation or of growth; but I have not been able to come to a decisive opinion on the point. From some conversation I had with Dr. Siemens on the subject, I gather that the characteristics were more those of dark colour and vigour than of tendency to great extension in size. The dark green colour we may suppose to indicate a liberal production of chlorophyll; but if the depth of colour was more than normal, it might be concluded that the chlorophyll had not performed its due amount of assimilation work. In regard to this point, attention may be called to the fact that Dr. Siemens refers to the abundance of the blue or actinic rays in the electric arc, conditions which would not be supposed specially to favour assimilation. On the other hand, the vigour, rather than characteristic extension in size, would seem to indicate a limitation of what is technically called growth, under the influence of the almost continuous light.

Among the numerous field experiments made at Rothamsted, we have many examples of great variation in depth of green colour of the vegetation growing on plots side by side under known differences as to manuring; and we have abundant evidence of difference of composition, and of rate of carbon-assimilation, coincidently with these different shades of colour. One or two instances will strikingly illustrate the point under consideration.

There are two plots side by side in the series of experiments on permanent grass land, each of which received during six consecutive years precisely the same amount of a mixed mineral manure, including potass, and the same amount of nitrogen in the form of ammonia salts. After those six years, one of the two plots was still manured in exactly the same way each year; whilst the other was so, with one exception—namely, the potass was now excluded from the manure. Calculation shows that there was a great excess of potass applied during the first six years; and there was no marked diminution of produce during the five or six years succeeding the cessation of the application. But each year subsequently, up to the present time, now a period of fourteen years, or of nineteen since the exclusion of the potass, the falling off in produce has been very great.

The point of special interest is, however, that all but identically the same amount of nitrogen has been taken up by the herbage growing with the deficiency of potass as by that with the continued supply of it. The colour of the vegetation with the deficiency of potass has been very much darker green than that with the full supply of it. Nevertheless, taking the average of the eight years succeeding

the first six of the exclusion of the potass, there has been nearly 400 lbs. less carbon assimilated per acre per annum; and in some of the still later years the deficiency has been very much greater than this.

We have here, then, the significant fact that an equal amount of nitrogen was taken up in both cases, that chlorophyll was abundantly produced, but that the full amount of carbon was not assimilated. In other words, the nitrogen was there, the chlorophyll was there, there was the same sun-light for both plots; but the assimilation-work was not done where there was not a due supply of potass.

Again, in the field in which barley has now been grown for twenty-nine years in succession, there are two plots which have annually received the same amount of nitrogen—the one in conjunction with salts of potass, soda, and magnesia; and the other with the same, and superphosphate of lime in addition. The plot without the superphosphate of lime always maintains a darker green colour. At any given period of growth the dry substance of the produce would undoubtedly contain a higher percentage of nitrogen; but there has been a deficient assimilation of carbon, amounting to more than 500 lbs. per acre per annum, over a period of twenty-eight years. Here again, then, the nitrogen was there, the chlorophyll was there, the sun-light was there, but the work was not done.

It may be stated generally that, in comparable cases, depth of green colour, if not beyond a certain limit, may be taken to indicate corresponding activity of carbon assimilation; but the two instances cited are sufficient to show that we may, so far as the nitrogen, the chlorophyll, and the light are concerned, have the necessary conditions for full assimilation, but not corresponding actual assimilation.

It cannot, I think, fail to be recognised that in these considerations we have opened up to view a very wide field of research, and some of the points involved we may hope will receive elucidation from the further prosecution of Dr. Siemens's experiments. He will himself, I am sure, be the first to admit that what he has already accomplished has done more in raising than in settling important questions. I understand that he proposes to submit plants to the action of the separated rays of his artificial light, and the results obtained cannot fail to be of much interest. But it is obvious that the investigation should now pass from its present initiative character to that of a strictly quantitative inquiry. We ought to know not only that, under given conditions as to light, plants acquire a deeper green colour and attain maturity much earlier than under others, but how much matter is assimilated in each case, and something also of the comparative chemical characters of the products. As between the action of one description of light and another, and as between the greater or less continuity of exposure, we ought to be able to form a judgment whether the proper balance between assimilation on the one hand, and growth and proper maturation on the other, has been attained; whether the plants have taken up nitrogen and mineral matter, and produced chlorophyll, in a greater degree than the quantity and the quality of the light have been able to turn to account; or whether the conditions as to light have been such that the processes of transformation and growth from the reserve material provided by assimilation have not been normal, or have not kept pace with the production of that material.

But one word more in reference to Dr. Siemens's results and proposed extension of his inquiries. Even supposing that by submitting growing crops to continuous light by the aid of the electric light during the night, they could be brought to maturity within a period shorter than at present approximately in proportion to the increased number of hours of exposure, the estimates of the cost of illuminating the vegetation of an acre of land certainly do not seem to hold out any hope that agriculture is likely to derive benefit from such an application of science to its needs. If, however, the characters of growth and of maturation should prove to be suitable for the requirements of horticultural products of luxury and high value, it may possibly be otherwise with such productions.

The above considerations obviously suggest the question: What is the office of chlorophyll in the processes of vegetation? Is it, as has generally been assumed, confined to effecting, in some way not yet clearly understood, carbon assimilation, and, this done, its function ended? Or is it, as Pringsheim has recently suggested,

chiefly of avail in protecting the subjacent cells and their contents from those rays of light which would be adverse to the secondary processes which have been distinguished as growth?

Appropriate as it would seem that I should attempt to lay before you a *résumé* of results bearing upon the points herein involved, so numerous and so varied have been the investigations which have been undertaken on the several branches of the question in recent years, that adequately to discuss them would occupy the whole time and space at my disposal. I must therefore be content thus to direct attention to the subject and pass on to other points.

It has been shown that the plant may receive abundance of nitrogen, may produce abundance of chlorophyll, and may be subject to the influence of sufficient light, and yet not assimilate a due amount of carbon. On the other hand, it has been seen that the mineral constituents may be liberally provided, and yet, in the absence of a sufficient supply of nitrogen in an available condition, the deficiency in the assimilation of carbon will be still greater. In fact, assuming all the other necessary conditions to be provided, it was seen that the amount of carbon assimilated depended on the available supply of nitrogen.

In a certain general sense it may be said that the success of the cultivator may be measured by the amount of carbon he succeeds in accumulating in his crops. And as, other conditions being provided, the amount of carbon assimilated depends on the supply of nitrogen in an available form within the reach of the plants, it is obvious that the question of the sources of the nitrogen of vegetation is one of first importance. Are they the same for all descriptions of plants? Are they to be sought entirely in the soil, or entirely in the atmosphere, or partly in the one and partly in the other?

These are questions which Mr. Lawes and myself have discussed so frequently that it might seem some apology was due for recurring to the subject here, especially as I referred to it in some of its aspects before this Section at the Sheffield Meeting last year. But the subject still remains one of first importance to agriculture, and it could not be omitted from consideration in such a review as I have undertaken to give. Moreover, there are some points connected with it still unsettled, and some still disputed.

It will be remembered that De Saussure's conclusion was that plants did not assimilate the free or uncombined nitrogen of the atmosphere, and that they derived their nitrogen from the compounds of it existing in the atmosphere, and especially in the soil. Liebig, too, concluded that plants do not assimilate nitrogen from the store of it existing in the free or uncombined state, but that ammonia was their main source, and he assumed the amount of it annually coming down in rain to be much more than we now know to be the case.

Referring to our previous papers for full details respecting most of the points in question, I will state, as briefly as I can, the main facts known—first in regard to the amount of the measurable, or as yet measured, annual deposition of combined nitrogen from the atmosphere; and secondly as to the amount of nitrogen annually assimilated over a given area by different crops—so that some judgment may be formed as to whether the measured atmospheric sources are sufficient for the requirements of agricultural production, or whether, or where, we must look for other supplies?

First, as to the amount of combined nitrogen coming down as ammonia and nitric acid in the measured aqueous deposits from the atmosphere.

Judging from the results of determinations made many years ago, partly by Mr. Way, and partly by ourselves, in the rain, &c., collected at Rothamsted; from the results of numerous determinations made much more recently by Professor Frankland in the deposits collected at Rothamsted, and also in rain collected elsewhere; from the results obtained by Boussingault in Alsace; from those of Marié-Davy at the Meteorological Observatory at Montsouris, Paris; and from those of many others made in France and Germany—we concluded, some years ago, that the amount of combined nitrogen annually so coming down from the atmosphere would not exceed 8 or 10 lbs. per acre per annum in the open country in Western Europe. Subsequent records would lead to the conclusion that this

estimate is more probably too high than too low. And here it may be mentioned in passing, that numerous determinations of the nitric acid in the drainage water collected from land at Rothamsted, which had been many years unmanured, indicate that there may be a considerable annual loss by the soil in that way; indeed, probably sometimes much more than the amount estimated to be annually available from the measured aqueous deposits from the atmosphere.

It should be observed, however, that the amount of combined nitrogen, especially of ammonia, is very much greater in a given volume of the minor aqueous deposits than it is in rain; and there can be no doubt that there would be more deposited within the pores of a given area of soil than on an equal area of the non-porous even surface of a rain-gauge. How much, however, might thus be available beyond that determined in the collected and measured aqueous deposits, the existing evidence does not afford the means of estimating with any certainty.

The next point to consider is—What is the amount of nitrogen annually obtained over a given area, in different crops, when they are grown without any supply of it in manure? The field experiments at Rothamsted supply important data relating to this subject.

Thus, over a period of 32 years (up to 1875 inclusive), wheat yielded an average of 20·7 lbs. of nitrogen per acre per annum, without any manure; but the annual yield has declined from an average of more than 25 lbs. over the first 8, to less than 16 lbs. over the last 12, of those 32 years; and the yield (it is true with several bad seasons), has been still less since.

Over a period of 24 years, barley yielded 18·3 lbs. of nitrogen per acre per annum, without any manure; with a decline from 22 lbs. over the first 12, to only 14·6 lbs. over the next 12 years.

With neither wheat nor barley did a complex mineral manure at all materially increase the yield of nitrogen in the crops.

A succession of so-called 'root crops'—common turnips, Swedish turnips, and sugar beet (with 3 years of barley intervening after the first 8 years)—yielded, with a complex mineral manure, an average of 26·8 lbs. of nitrogen per acre per annum over a period of 31 years. The yield declined from an average of 42 lbs. over the first 8 years, to only 13·1 lbs. (in sugar beet) over the last 5 of the 31 years; but it has risen somewhat during the subsequent 4 years, with a change of crop to mangolds.

With the leguminous crop, beans, there was obtained, over a period of 24 years, 31·3 lbs. of nitrogen per acre per annum without any manure, and 45·5 lbs. with a complex mineral manure, including potass (but without nitrogen). Without manure the yield declined from 48·1 lbs. over the first 12 years to only 14·6 lbs. over the last 12; and with the complex mineral manure it declined from 61·5 lbs. over the first 12, to 29·5 lbs. over the last 12, years of the 24.

Again, an ordinary rotation of crops—of turnips, barley, clover or beans, and wheat—gave over a period of 28 years an average of 36·8 lbs. of nitrogen per acre per annum without any manure, and of 45·2 lbs. with superphosphate of lime alone, applied once every four years, that is for the root crop. Both without manure, and with superphosphate of lime alone, there was a considerable decline in the later courses.

A very remarkable instance of nitrogen yield is the following—in which the results obtained when barley succeeds barley, that is when one gramineous crop succeeds another, are contrasted with those when a leguminous crop, clover, intervenes between the two cereal crops. Thus, after the growth of six grain crops in succession by artificial manures alone, the field so treated was divided, and, in 1873, on one half barley, and on the other half clover, was grown. The barley yielded 37·3 lbs. of nitrogen per acre, but the three cuttings of clover yielded 151·3 lbs. In the next year, 1874, barley succeeded on both the barley and the clover portions of the field. Where barley had previously been grown, and had yielded 37·3 lbs. of nitrogen per acre, it now yielded 39·1 lbs.; but where the clover had previously been grown, and had yielded 151·3 lbs. of nitrogen, the barley succeeding it gave 69·4 lbs., or 30·3 lbs. more after the removal of 151·3 lbs. in clover, than after the removal of only 37·3 lbs. in barley.

Nor was this curious result in any way accidental. It is quite consistent with

agricultural experience that the growth and removal of a highly nitrogenous leguminous crop should leave the land in high condition for the growth of a gramineous corn crop, which characteristically requires nitrogenous manuring; and the determinations of nitrogen in numerous samples of the soil taken from the two separate portions of the field, after the removal of the barley, and the clover, respectively, concurred in showing considerably more nitrogen, especially in the first 9 inches of depth, in the samples from the portion where the clover had been grown, than in those from the portion whence the barley had been taken. Here, then, the surface soil at any rate, had been considerably enriched in nitrogen by the growth and removal of a very highly nitrogenous crop.

Lastly, clover has now been grown for twenty-seven years in succession, on a small plot of garden ground which had been under ordinary garden cultivation for probably two or three centuries. In the fourth year after the commencement of the experiment, the soil was found to contain, in its upper layers, about four times as much nitrogen as the farm-arable-land surrounding it; and it would doubtless be correspondingly rich in other constituents. It is estimated that an amount of nitrogen has been removed in the clover crops grown, corresponding to an average of not far short of two hundred pounds per acre per annum; or about ten times as much as in the cereal crops, and several times as much as in any of the other crops, growing on ordinary arable land; and, although the yield continues to be very large, there has been a marked decline over the second half of the period compared with the first. Of course, calculations of the produce of a few square yards into quantities per acre can only be approximately correct. But there can at any rate be no doubt whatever, that the amount of nitrogen annually removed has been very great; and very far beyond what it would be possible to attain on ordinary arable land; where, indeed, we have not succeeded in getting even a moderate growth of clover for more than a very few years in succession.

One other illustration should be given of the amounts of nitrogen removed from a given area of land by different descriptions of crop, namely, of the results obtained when plants of the gramineous, the leguminous, and other families, are growing together, as in the mixed herbage of grass-land.

It is necessary here to remind you that gramineous crops grown separately on arable land, such as wheat, barley, or oats, contain a comparatively small percentage of nitrogen, and assimilate a comparatively small amount of it over a given area. Yet, nitrogenous manures have generally a very striking effect in increasing the growth of such crops. The highly nitrogenous leguminous crops (such as beans and clover), on the other hand, yield, as has been seen, very much more nitrogen over a given area, and yet they are by no means characteristically benefited by direct nitrogenous manuring; whilst, as has been shown, their growth is considerably increased, and they yield considerably more nitrogen over a given area, under the influence of purely mineral manures, and especially of potass manures. Bearing these facts in mind, the following results, obtained on the mixed herbage of grass land, will be seen to be quite consistent.

A plot of such mixed herbage, left entirely unmanured, gave over twenty years, an average of 33 pounds of nitrogen per acre per annum. Over the same period another plot, which received annually a complex mineral manure, including potass, during the first six years, but excluding it during the last fourteen years, yielded 46·3 lbs of nitrogen; whilst another, which received the mixed mineral manure, including potass, every year of the twenty, yielded 55·6 lbs. of nitrogen per acre per annum. Without manure, there was some decline of yield in the later years; with the partial mineral manuring there was a greater decline; but with the complete mineral manuring throughout the whole period, there was even some increase in the yield of nitrogen in the later years.

Now, the herbage growing without manure comprised about fifty species, representing about twenty natural families; that growing with the limited supply of potass comprised fewer species, but a larger amount of the produce, especially in the earlier years, consisted of leguminous species, and the yield of nitrogen was greater. Lastly, the plot receiving potass every year yielded still more leguminous herbage, and, accordingly, still more nitrogen.

The most striking points brought out by the foregoing illustrations are the following:—

First. Without nitrogenous manure, the gramineous crops annually yielded, for many years in succession, much more nitrogen over a given area than is accounted for by the amount of combined nitrogen annually coming down in the measured aqueous deposits from the atmosphere.

Second. The root crops yielded more nitrogen than the cereal crops, and the leguminous crops very much more still.

Third. In all cases—whether of cereal crops, root crops, leguminous crops, or a rotation of crops—*the decline in the annual yield of nitrogen, when none was supplied, was very great.*

How are these results to be explained? Whence comes the nitrogen? and especially whence comes the much larger amount taken up by plants of the leguminous and some other families, than by the gramineæ? And, lastly, what is the significance of the great decline in the yield of nitrogen in all the crops when none is supplied in the manure?

Many explanations have been offered. It has been assumed that the combined nitrogen annually coming down from the atmosphere is very much larger than we have estimated it, and that it is sufficient for all the requirements of annual growth. It has been supposed that 'broad-leaved plants' have the power of taking up nitrogen in some form from the atmosphere, in a degree, or in a manner, not possessed by the narrow-leaved gramineæ. It has been argued that, in the last stages of the decomposition of organic matter in the soil, hydrogen is evolved, and that this nascent hydrogen combines with the free nitrogen of the atmosphere, and so forms ammonia. It has been suggested that ozone may be evolved in the oxidation of organic matter in the soil, and that, uniting with free nitrogen, nitric acid would be produced. Lastly, it has by some been concluded that plants assimilate the free nitrogen of the atmosphere, and that some descriptions are able to do this in a greater degree than others.

We have discussed these various points on more than one occasion; and we have given our reasons for concluding that none of the explanations enumerated can be taken as accounting for the facts of growth.

Confining attention here to the question of the assimilation of free nitrogen by plants, it is obvious that, if this were established, most of our difficulties would vanish. This question has been the subject of a great deal of experimental inquiry, from the time that Boussingault entered upon it, about the year 1837, nearly up to the present time. About twenty years ago it was elaborately investigated at Rothamsted. In publishing the results of that inquiry, those of others relating to it were fully discussed; and although the recorded evidence is admittedly very conflicting, we then came to the conclusion, and still adhere to it, that the balance of the direct experimental evidence on the point is decidedly against the supposition of the assimilation of free nitrogen by plants. Indeed, the strongest argument we know of in its favour, is, that some such explanation is wanted.

Not only is the balance of direct experimental evidence against the assumption that plants assimilate free or uncombined nitrogen, but it seems to us that the balance of existing indirect evidence is also in favour of another explanation of our difficulties.

I have asked what is the significance of the gradual decline of produce of all the different crops when continuously grown without nitrogenous manure? It cannot be that, in growing the same crop year after year on the same land, there is any residue left in the soil that is injurious to the subsequent growth of the same description of crop; for (excepting the beans) more of each description of crop has been grown year after year on the same land than the average yield of the country at large under ordinary rotation, and ordinary treatment—provided only, that suitable soil-conditions were supplied. Nor can the diminishing produce, and the diminishing yield of nitrogen, be accounted for on the supposition that there was a deficient supply of available mineral constituents in the soil. For, it has been shown that the cereals yielded little more, and declined nearly as much as without manure, when a complex mineral manure was used, such as was proved to be ade-

quate when available nitrogen was also supplied. So far as the root crops are concerned, the yield of nitrogen, though it declined very much, was greater at first, and on the average, than in the case of the cereals. As to the leguminosæ, which require so much nitrogen from somewhere, it is to be observed that on ordinary arable land the yield has not been maintained under any conditions of manuring; and the decline was nearly as marked with mineral manures as without any manure. Compared with the growth of the leguminosæ on arable land, the remarkable result with the garden clover would seem clearly to indicate that the question was one of soil, and not of atmospheric supply. And the fact that all the other crops will yield full agricultural results even on ordinary arable land, when proper manures are applied, is surely very strong evidence that it is with them, too, a question of soil, and not of atmospheric supply.

But we have other evidence leading to the same conclusion. Unfortunately we have not reliable samples of the soil of the different experimental fields taken at the commencement of each series of experiments, and subsequently at stated intervals. We have, nevertheless, in some cases, evidence sufficient to show whether or not the nitrogen of the soil has suffered diminution by the continuous growth of the crop without nitrogenous manure.

Thus, we have determined the nitrogen in the soil of the continuously unmanured wheat plot at several successive periods, and the results prove that a gradual reduction in the nitrogen of the soil is going on; and, so far as we are able to form a judgment on the point, the diminution is approximately equal to the nitrogen taken out in crops; and the amount estimated to be received in the annual rainfall is approximately balanced by the amount lost by the land as nitrates in the drainage water.

In the case of the continuous root-crop soil, on which the decline in the yield of nitrogen in the crop was so marked, the percentage of nitrogen, after the experiment had been continued for twenty-seven years, was found to be lower where no nitrogen had been applied than in any other arable land on the farm which has been examined.

In the case of the experiments on the mixed herbage of grass land, the soil of the plot which, under the influence of a mixed mineral manure, including potass, had yielded such a large amount of leguminous herbage and such a large amount of nitrogen, showed, after twenty years, a considerably lower percentage of nitrogen than that of any other plot in the series.

Lastly, determinations of nitrogen in the garden soil which has yielded so much nitrogen in clover, made in samples collected in the fourth and the twenty-sixth years of the twenty-seven of the experiments, show a very large diminution in the percentage of nitrogen. The diminution, to the depth of 9 inches only, represents approximately three-fourths as much as the amount estimated to be taken out in the clover during the intervening period; and the indication is, that there has been a considerable reduction in the lower depths also. It is to be supposed, however, that there would be loss in other ways than by the crop alone.

I would ask, Have we not in these facts—that full amounts of the different crops can be grown, provided proper soil-conditions are supplied; that without nitrogenous manure the yield of nitrogen in the crop rapidly declines; and that, coincidently with this, there is a decline in the percentage of nitrogen in the soil—have we not in these facts cumulative evidence pointing to the soil, rather than to the atmosphere, as the source of the nitrogen of our crops?

In reference to this point, I may mention that the ordinary arable soil at Rothamsted may be estimated to contain about 3000 lbs. of nitrogen per acre in the first 9 inches of depth, about 1700 lbs. in the second 9 inches and about 1500 lbs. in the third 9 inches—or a total of about 6200 lbs. per acre to the depth of 27 inches.

In this connection, it is of interest to state that a sample of Oxford clay, obtained in the sub-Wealden exploration boring, at a depth of between 500 and 600 feet (and which was kindly given to me by the President of the Association, Professor Ramsay, some years ago), showed, on analysis at Rothamsted, approximately the same percentage of nitrogen as the subsoil at Rothamsted taken to the depth of about 4 feet only.

Lastly, in a letter received from Boussingault some years ago, referring to the sources whence the nitrogen of vegetation is derived, he says:—

'From the atmosphere, because it furnishes ammonia in the form of carbonate, nitrates, or nitrites, and various kinds of dust. Theodore de Saussure was the first to demonstrate the presence of ammonia in the air, and consequently in meteoric waters. Liebig exaggerated the influence of this ammonia on vegetation, since he went so far as to deny the utility of the nitrogen which forms a part of farm-yard manure. This influence is nevertheless real, and comprised within limits which have quite recently been indicated in the remarkable investigations of M. Schlösing.

'From the soil, which, besides furnishing the crops with mineral alkaline substances, provides them with nitrogen, by ammonia, and by nitrates, which are formed in the soil at the expense of the nitrogenous matters contained in diluvium, which is the basis of vegetable earth; compounds in which nitrogen exists in stable combination, only becoming fertilising by the effect of time. If we take into account their immensity, the deposits of the last geological periods must be considered as an inexhaustible reserve of fertilising agents. Forests, prairies, and some vineyards have really no other manures than what are furnished by the atmosphere and by the soil. Since the basis of all cultivated land contains materials capable of giving rise to nitrogenous combinations, and to mineral substances, assimilable by plants, it is not necessary to suppose that in a system of cultivation the excess of nitrogen found in the crops is derived from the free nitrogen of the atmosphere. As for the absorption of the gaseous nitrogen of the air by vegetable earth, I am not acquainted with a single irreproachable observation that establishes it; not only does the earth not absorb gaseous nitrogen, but it gives it off, as you have observed in conjunction with Mr. Lawes, as Reiset has shown in the case of dung, as M. Schlösing and I have proved in our researches on nitrification.

'If there is one fact perfectly demonstrated in physiology, it is this of the non-assimilation of free nitrogen by plants; and I may add by plants of an inferior order, such as mycoderms and mushrooms (Translation).'

If, then, our soils are subject to a continual loss of nitrogen by drainage, probably in many cases more than they receive of combined nitrogen from the atmosphere—if the nitrogen of our crops is derived mainly from the soil, and not from the atmosphere—and if, when due return is not made from without, we are drawing upon what may be termed the store of nitrogen of the soil itself—is there not, in the case of many soils at any rate, as much danger of the exhaustion of their available nitrogen as there has been supposed to be of the exhaustion of their available mineral constituents?

I had hoped to say something more about soils, to advance our knowledge respecting which an immense amount of investigation has been devoted of late years, but in regard to which we have yet very much more to learn. I must, however, now turn to other matters.

I have thus far directed attention to some points of importance in connection with the sources of the constituents of our crops, and I must now briefly refer to some in connection with the composition, and to some relating to the uses, of the crops themselves.

As to composition, I must confine myself to indicating something of what is known of the condition of the nitrogen in our various crops; though I had intended to say something respecting the carbo-hydrates, and especially respecting the various members of the cellulose group.

As to the nitrogen—in our first experiments on the feeding of animals, made in 1847, 1848, and 1849, the results of which were published in the last-mentioned year—we found that, in the case of succulent roots used as food, not only were they not of value as food in proportion to their richness in nitrogen, but when the percentage of it was higher than a certain normal amount, indicating relative succulence and immaturity, they were positively injurious to the animals. So marked was the variation of result according to the condition of maturity or otherwise of the foods employed, that, when reviewing the results of the experiments which had up

to that time been conducted, in a paper read before this Section of the British Association at the Belfast Meeting in 1852 (and which was published in full in the annual volume[1]), we stated that the mode of estimating the amount of proteine compounds by multiplying the percentage of nitrogen by 6·3 was far from accurate, especially when applied to succulent vegetable foods, and that the individual compounds ought to be determined. The Rothamsted Laboratory staff was, however, much smaller then than it is now, and with the pressure of many other subjects upon us, it was at that time quite impossible to follow up the enquiry in that direction.

It is, indeed, only within the last ten years or so, that the question has been taken up at all systematically; but we are already indebted to E. Schulze, A. Urick, Church, Sachsse, Maercker, Kellner, Vines, Emmerling, and others, for important results relating to it.

Our knowledge in regard to the subject is, however, still very imperfect. But it is in progress of investigation from two distinctly different points of view—from that of the vegetable physiologist, and that of the agricultural chemist. The vegetable physiologist seeks to trace the changes that occur in the germination of the seed, and during the subsequent life-history of the plant, to the production of seed again. The agricultural chemist takes the various vegetable products in the condition in which they are used on the farm, or sold from it. And as a very large proportion of what is grown, such as grass, hay, roots, tubers, and various green crops, are not matured productions, it comes to be a matter of great importance to consider whether or not any large proportion of the nitrogenous contents of such products is in such condition as not to be of avail to the animals which consume them in their food?

We cannot say that the whole of the nitrogen in the seeds with which we have to deal exists as albuminoids. But we may safely assume that the nearer they approach to perfect ripeness, the less of non-albuminoid nitrogenous matters will they contain; and, in the case of the cereal grains at any rate, it is probable that if really perfectly ripe they will contain very nearly the whole of their nitrogen as albuminoids. With regard to some leguminous and other seeds, which contain peculiar nitrogenous bodies, the range may, however, be wider.

But whatever the condition of the nitrogenous bodies in the seeds we grow or sow, with germination begins a material change. Albuminoids are transformed into peptones, or peptone-like bodies, or degraded into various amido- or other compounds. Such change into more soluble and more diffusible bodies is, it is to be supposed, essential to their free migration, and to their subserviency to the purposes of growth. In the case of the germination, especially of some leguminous seeds, asparagine has been found to be a very prominent product of such degradation of the albuminoids; but it would seem that this disappears as the green parts are developed. But now the plant begins to receive supplies of nitrogen from the soil, as nitrates or ammonia, and it would seem that amides constitute a considerable proportion of the produced nitrogenous bodies, apparently as an intermediate stage in the formation of albuminoids. At any rate, such bodies are found to exist largely in the immature plant; whilst the amount of them diminishes as the plant, or its various parts, approach to maturity.

But not only have we thus, in unripened vegetable productions, a greater or less, and sometimes a very large, proportion of the nitrogenous bodies formed within the plant, existing as amido-compounds, but we may have a large amount existing in the juices as nitric acid, and some as ammonia, &c. Thus, E. Schulze determined the nitric acid in various 'roots;' and he found that, in some mangolds, more than one-third of the total nitrogen existed in that form, and about one-tenth as much as ammonia. In a considerable series at Rothamsted, we have found an extremely variable proportion existing as nitric acid, according to the size, succulence, or degree of maturity, of the roots; the amount being, as a rule, the least with the ripest and less highly nitrogenous roots, and the most with the most succulent, unripe, and highly nitrogenous ones. In some cases it reached as much as from

[1] 'On the Composition of Foods in relation to Respiration and the Feeding of Animals.'

20 to nearly 30 per cent. of the total nitrogen. In many other immature vegetable products nitric acid and ammonia have been found; but, so far as I remember, in none in anything like so large a proportion as in the so-called 'root-crops,' especially manoglds. In many, however, the quantity appears to be immaterial; and it is remarkable that whilst there is so much in the 'roots,' little or none is found in potatos.

No wonder that, in the experiments already referred to, we found the feeding result to be the worse the more succulent and immature the roots, and the higher their percentage of nitrogen, accordingly.

But it is to the difference in amount of the albuminoid bodies themselves, in different descriptions of vegetable produce, that I wish specially to direct attention, making, however, some reference to what is known of the proportion of the nitrogen existing as amido-compounds.

In some mangolds E. Schulze found only from about 20 to 22 per cent. of their total nitrogen to exist as insoluble and soluble albumin. But he found in one case 32·5, and in the other 40·8, per cent. of the total nitrogen as amides. In a large series of determinations at Rothamsted, by Church's method, we found a variation of from under 20 to over 40 per cent. of the total nitrogen of mangolds to exist as albuminoids; or, in other words, from nearly 60 to over 80 per cent. of it in the non-albuminoid condition.

In potatos Schulze found from under 50 to 65 per cent. of the total nitrogen as soluble and insoluble albumin, and from 27·7 to 49·1 per cent. as neutral and acid amides. In a series of potatos grown at Rothamsted, under very various conditions as to manuring, and in two different seasons, we found the nitrogen as albuminoids to range from little over 50 to more than 71 per cent. of the total nitrogen; leaving, of course, from less than 30 to nearly 50 per cent. to be accounted for in other ways.

Kellner determined the amount of nitrogen as albuminoids, and as amido-compounds, in a considerable series of green foods, both leguminous and gramineous, cut at different stages of their growth. The proportion of the total nitrogen not as albuminoids was, upon the whole, greater in the leguminosæ than in the gramineæ. In both, however, the proportion as albuminoids increased as the plants approached to maturity. The proportion as albuminoids was in all these products very much larger than in roots, and generally larger than in potatos. In the case of first-crop meadow hay, we found in the separated gramineous herbage 76·4, in the leguminous herbage 82, and in the miscellaneous herbage 80·3 per cent of the nitrogen as albuminoids; and in the second crop 86·2 per cent. in the gramineous, 88·3 per cent. in the leguminous, and 88·1 per cent. in the miscellaneous herbage. How far the higher proportion of the nitrogen as albuminoids in the second crops is to be taken as any indication of the characteristics of the autumn growth, or how far it is to be attributed to the accidental condition of the weather, may be a question.

These illustrations are sufficient to give some idea of the range and proportion of the nitrogen in different feeding crops which does not exist as albuminoids; and they are sufficient to show that a very large proportion of the non-albuminoid matter exists as various amido-compounds. The question arises, therefore, whether these bodies contribute in any way to the nutrition of the animals which feed upon them? We have but little experimental evidence on this point. As green herbage is the natural food of many descriptions of animal, we might suppose that characteristic constituents of it would not be without some value as food; but the cultivated root crops are much more artificial productions, and it is in them that we find such a very large proportion of non-albuminoid nitrogen. With respect to some of the amido-compounds, at any rate, direct experiments seem to show that they are digested in the animal body, and increase the elimination of urea. Weiske and Schrodt found that rabbits receiving, as their only nitrogenous food, either asparagine or gelatin, wasted and died; but a rabbit receiving both asparagine and gelatin increased in weight and survived to the end of the experiment, which lasted seventy-two days. From the results of other experiments made with sheep, they concluded that both asparagine and gelatin protect the albuminoids of the body from oxidation.

These considerations lead me, in conclusion, to refer briefly—and I promise it shall be as briefly as is consistent with clearness—to the two very much disputed questions of *the origin of muscular power*, and *the sources of the fat of the animal body*. These subjects Mr. Lawes and myself have frequently discussed elsewhere; but as the controversy has assumed a new phase quite recently, it seems desirable and appropriate that I should recur to it on the present occasion.

With regard to the question of the sources in the food of the fat of the animal body, Liebig originally maintained that although fat might be formed from the nitrogenous compounds within the body, the main source of it in the herbivora was the carbo-hydrates. In his later writings, he sharply criticised the experiments and arguments of those who have maintained the formation of fat chiefly from the proteine compounds; but he at the same time seems to attach more importance to that source than he formerly did. He gives it as his opinion that the question cannot be settled by experiments with herbivora. He adds that what we know with certainty is that, with these animals, albuminates and carbo-hydrates work together to produce fat; but whether the non-nitrogenous product, fat, has its origin in the albumin or in the carbo-hydrate, h considers it not easy to determine.

At the time when we commenced our experiments on the feeding of animals in 1847, the question whether the fat of the animals fed for human food was mainly derived from albuminoids or from carbo-hydrates had been scarcely raised, or at least it was not prominent. The question then was rather—whether the herbivora received their fat ready formed in their food, or whether it was produced within the body—the latter view being that which Liebig had so forcibly urged, at the same time maintaining that at any rate its chief source was the carbo-hydrates. Accordingly, our experiments were not specially arranged to determine whether or not the whole of the fat produced could or could not be derived from the albuminoids.

For each description of animal, oxen, sheep, and pigs, such foods as had been established by common experience to be appropriate were selected. The general plan of the experiments was—to give to one set a fixed amount of a recognised good food, containing known quantities of nitrogen, fatty matter, &c.; to another set the same amount of another food, of different characters in these respects; to other sets also fixed amounts of other foods in the same way; and then there was given, to the whole series, the same complementary food *ad libitum*. Or, to one set was supplied a uniform food rich in nitrogen, and to others uniform foods poorer in nitrogen, and so on, in each case *ad libitum*.

It will be seen that, in this way, a great variety of dietaries was arranged; and it will be observed that in each case the animals themselves fixed their consumption, according to the requirements of the system.

As already indicated, the individual nitrogenous and non-nitrogenous compounds of the foods were not determined. As a rule, the constituents determined were —the total dry matter, the ash, the fatty matter, and the nitrogen; from which last the amount of nitrogenous compounds it might represent was calculated by the usual factor. But, as already intimated, the results so obtained were only used with considerable reservation, especially in the case of all immature vegetable produce. Nor was the crude fibre determined; but, as in the case of the estimated nitrogenous substance, when interpreting the results, it was always considered whether or not the food contained much or little of probably indigestible woody matter.

The animals being periodically weighed, we were thus able to calculate the amounts of the so-estimated nitrogenous substance, and of the total non-nitrogenous substance, including and excluding fat, consumed—*for a given live-weight within a given time*, and *to produce a given amount of increase in live-weight*.

Experiments were made with a large number of sheep, and a large number of pigs. And, even without making allowance for the different condition of the nitrogenous or of the non-nitrogenous constituents, in comparable foods, the results obtained uniformly indicated that both the amount consumed by a given live-weight of animal within a given time, and that required to produce a given amount of increase, were determined much more by the amount of the non-nitrogenous than by that of

the nitrogenous constituents which the food supplied. And when allowance was made for the different condition of the nitrogenous constituents, and for the greater or less amount of the non-nitrogenous ones which would probably be indigestible and effete, the indications were still more remarkable and conclusive.

In very many cases the animals were slaughtered, and carefully examined as to whether the tendency of development had been more that of growth in frame and flesh, or in fatness. Here, again, the evidence was clear—that the tendency to growth in frame and flesh was favoured by a high proportion of nitrogen in the food, and that to the production of fat by a high proportion of digestible non-nitrogenous constituents.

In a few cases the actual amount of fat in the animals in the lean, and in the fat condition, was determined; and the results admitted of no doubt whatever that a very large proportion of the stored-up fat could not have been derived from the fatty matter of the food, and must have been produced within the body.

So decisive and consistent were the very numerous and very varied results in regard to these points, that we had no hesitation in concluding—not only that much of the fat stored up was produced within the body, but that the source of much, at any rate, of the produced fat must have been the non-nitrogenous constituents of the food—in other words, the *carbo-hydrates.*

As already stated, however, as the question whether the source of the produced fat was the proteine compounds or the carbo-hydrates was not then prominent, we had not so arranged the experiments as to obtain the largest possible increase in fat with the smallest possible supply of nitrogenous compounds in the food; nor did we then even calculate whether or not there was sufficient nitrogenous matter consumed to be the source of the whole of the fat produced.

This question, indeed, excited very little interest, until, at a meeting of the Congress of Agricultural Chemists held at Munich in 1865 (at which I happened to be present), Professor Voit, from the results of experiments made in Pettenkofer's respiration apparatus with dogs fed on flesh, announced his conclusion that fat must have been produced from the nitrogenous substance, and that this was probably the chief, if not the only, source of the fat, even of herbivora—an opinion which he subsequently urged much more positively.

In the discussion which followed the reading of Professor Voit's paper, Baron Liebig forcibly called in question his conclusions; maintaining not only that it was inadmissible to form conclusions on such a point in regard to herbivora, from the results of experiments made with carnivora, but also that direct quantitative results obtained with herbivorous animals had afforded apparently conclusive evidence in favour of the opposite view.

Voit's paper excited considerable controversy, in which Mr. Lawes and myself joined. We maintained that experiments to determine such a question should be made, not with carnivora or omnivora fed on flesh, but with herbivora fed on their appropriate fattening food, and on such herbivora as common experience showed to be pre-eminently fat-producers. We pointed out [1] that the pig comprised, for a given live-weight, a comparatively small proportion of alimentary organs and contents; that, compared with that of the ruminants, his food was of a high character, yielding, for a given weight of it, much more total increase, much more fat, and much less necessarily effete matter; that, in proportion to his weight, he consumes a larger amount of food, and yields a larger amount, both of total increase and of fat, within a given time; and, lastly, that he contains a larger proportion of fat, both in a given live weight and in his increase whilst fattening.

It is obvious that, with these characteristics, there is much less probable range of error in calculating the amount and the composition of the increase in live-weight in relation to the amount and composition of the food consumed, than in the case of the ruminants; and that, therefore, the pig is very much more appropriate for the purpose of experiments to determine the sources in its food of the fat it produces.

Accordingly, we calculated a number of our early experiments made with pigs, to determine whether or not the nitrogenous substance they consumed was suffi-

[1] 'On the Sources of the Fat of the Animal Body,' *Phil. Mag.*, December 1866.

cient for the formation of the fat they produced. For simplicity of illustration, and to give every possible advantage to the view that nitrogenous substance might have been the source of the produced fat, we assumed the whole of the crude fat of the food to have been stored up in the animal—thus estimating a minimum amount to be produced. Then, again, we supposed the whole of the nitrogenous substance of the food to be perfectly digested, and to become available for the purposes of the system. Lastly, after deducting the amount of nitrogenous substance estimated to be stored up as such, the whole of the remainder was reckoned to be so broken up that no other carbon-compounds than fat and urea would be produced.

The result was, that, even adopting these inadmissible assumptions, in all the cases in which, according to common experience, the food was admittedly the most appropriate for the fattening of the animal, the calculation showed that a large amount of fat had been produced which could not have been derived from the nitrogenous substance of the food, and must therefore have had its source in the carbo-hydrates. Such a result is, moreover, entirely accordant with experience in practical feeding.

Reviewing the whole subject in great detail in 1869, Professor Voit refers to these results and calculations. He confesses that he has not been able to get a general view of the experiments from the mass of figures recorded, and from his comments he shows that he has on some points misunderstood them. He admits, however, that, as the figures stand, it would appear that fat had, in some instances, been derived from the carbo-hydrates. Still, he says, he cannot allow himself to consider that a transformation of carbo-hydrates into fat has thus been proved.

Professor Emil von Wolff, again, in his 'Landwirthschaftliche Fütterungslehre,' referring to the same experiments, admits that they are almost incomprehensible unless we assume the direct concurrence of the carbo-hydrates in the formation of fat. He, nevertheless, seems to consider that evidence of the kind in question is inconclusive; and he suggests that experiments with pigs should be made in a respiration apparatus to determine the point.

Mr. Lawes and myself entertained, however, the utmost confidence that the question was of easy settlement without any such apparatus, provided only suitable animals and suitable foods were selected. I, accordingly, gave a paper on the subject in the *Section für Landwirthschaft- und Agricultur-Chemie*, at the *Naturforscher Versammlung* held at Hamburg in 1876.[1] The points which I particularly insisted upon were—that the pig should be the subject of experiment; that he should be allowed to take as much as he would eat of his most appropriate fattening food, so that his increase, and the fat he produced, should bear as large a proportion as possible to his weight, to the total food, and to the total nitrogenous substance consumed. Finally, it was maintained that, if these conditions were observed, and the constituents of the food determined, and those of the increase of the animal estimated according to recognised methods, the results could not fail to be perfectly conclusive, without the intervention, either of a respiration apparatus, or of the analysis of the solid and liquid matters voided.

Results so obtained were adduced in proof of the correctness of the conclusions arrived at. We at the same time admitted that, although, for reasons indicated, we had always assumed that fat was formed from the carbo-hydrates in the case of ruminants as well as of pigs, yet, as in our experiments with those animals we had supplied too large amounts of ready formed fat, or of nitrogenous matter, or of both, it could not be shown so conclusively by the same mode of calculation in their case as in that of pigs.

In the discussion which followed, Professor Henneberg agreed that it seemed probable that fat could be formed from the carbo-hydrates in the case of pigs. In the case of experiments with other animals, however, the amount of fat produced was too nearly balanced by the amount of fat and albuminous matters available, to afford conclusive evidence on the point.

Quite recently, Professor Emil von Wolff ('Landwirthschaftliche Jahrbücher,'

[1] The substance of that communication is given in the *Journal of Anatomy an Physiology*, vol. xi. part iv.

Band viii. 1879, Supplement) has applied the same mode of calculation to results obtained by himself with pigs some years ago. He concluded that the whole of the body fat could not have been formed without the direct co-operation of the carbo-hydrates of the food. But what is of greater interest still is, that he also calculated, in the same way, the results of some then quite recent experiments of Henneberg, Kern, and Wattenberg, with sheep. He thus found that, even including the whole of the estimated amides with the albumin, there must have been a considerable production of fat from the carbo-hydrates; and, excluding the amides, the amount reckoned to be derived from the carbo-hydrates was of course much greater.

I will only add, on this point, that, on re-calculating some of our early results with sheep, which did not afford sufficiently conclusive evidence when the whole of the nitrogen of the food was reckoned as albumin, these show a very considerable formation of fat from the carbo-hydrates, if deduction be made for the probable amount of non-albuminoid nitrogenous matter of the food.

We have now, then, the two agricultural chemists of perhaps the highest authority, both as experimenters and writers on this subject on the Continent, giving in their adhesion to the view, that the fat of the herbivora, which we feed for human food, may be, and probably is, largely produced from the carbo-hydrates. I dare say, however, that some physiologists will not change their view until Voit gives them sanction by changing his, which, so far as I know, he has not yet done.

The question which has been currently entitled that of '*The Origin of Muscular Power*,' or '*The Sources of Muscular Power*,' has also been the subject of much investigation, and of much conflict of opinion, since the first publication of Liebig's views respecting it in 1842.

As I have already pointed out, he then maintained that the amount of muscular tissue transformed, the amount of nitrogenous substance oxidated, was the measure of the force generated in the body. He accordingly concluded that the requirement for the nitrogenous constituents of food would be increased in proportion to the increase of the force expended. In his more recent writings on the subject, he freely criticises those who take an opposite view. He nevertheless grants that the secretion of urea is not a measure of the force exerted; but, on the other hand, he does not commit himself to the admission that the oxidation of the carbo-hydrates is a source of muscular power.

The results of our own early and very numerous feeding experiments were, as has been said, extremely accordant in showing that, provided the nitrogenous constituents in the food were not below a certain rather limited amount, it was the quantity of the digestible and available non-nitrogenous constituents, and not that of the nitrogenous substance, that determined—both *the amount consumed by a given live-weight within a given time*, and *the amount of increase in live-weight produced*. They also showed that one animal, or one set of animals, might consume two or three times as much nitrogenous substance in proportion to a given live-weight within a given time as others in precisely comparable conditions as to rest or exercise. It was further proved that they did not store up nitrogenous subtance at all in proportion to the greater or less amount of it supplied in the food, but that the excess reappeared in the liquid and solid matters voided.

So striking were these results, that we were led to turn our attention to human dietaries, and also to a consideration of the management of the animal body undergoing somewhat excessive labour, as, for instance, the hunter, the racer, the cab-horse, and the foxhound, and also pugilists and runners. Stated in a very few words, the conclusion at which we arrived from these inquiries (which were summarised in our paper given at Belfast in 1852) was—that, unless the system were overtaxed, the demand induced by an increased exercise of force was more characterised by an increased requirement for the more specially respiratory, than for the nitrogenous, constituents of food.

Soon afterwards, in 1854, we found by direct experiments with two animals in exactly equal conditions as to exercise, both being in fact at rest, that the amount of urea passed by one feeding on highly nitrogenous food was more than twice as great as that fed on a food comparatively poor in nitrogen.

It was clear, therefore, that the rule which had been laid down by Liebig, and

which has been assumed to be correct by so many writers, even up to the present time, did not hold good—namely, that 'The sum of the mechanical effects produced in two individuals, in the same temperature, is proportional to the amount of nitrogen in their urine; whether the mechanical force has been employed in voluntary or involuntary motions, whether it has been consumed by the limbs or by the heart and other viscera'—unless, indeed, as has been assumed by some experimenters, there is, with increased nitrogen in the food, an increased amount of mechanical force employed in the 'involuntary motions' sufficient to account for the increased amount of urea voided.

The question remained in this condition until 1860, when Bischoff and Voit published the results of a long series of experiments made with a dog. They found that, even when the animal was kept at rest, the amount of urea voided varied closely in proportion to the variation in the amount of nitrogenous substance given in the food—a fact which they explained on the assumption that there must have been a corresponding increase in the force exercised in the conduct of the actions proceeding within the body itself in connection with the disposal of the increased amount of nitrogeneous substance consumed. Subsequently, however, they found that the amount of urea passed by the animal was, with equal conditions as to food, &c., no greater when he was subjected to labour than when at rest; whilst, on the other hand, the carbonic acid evolved was much increased by such exercise. They accordingly somewhat modified their views.

In 1866 appeared a paper by Professors Fick and Wislicenus, giving the results obtained in a mountain ascent. They found that practically the amount of urea voided was scarcely increased by the labour thus undertaken. Professor Frankland gave an account of these experiments in a lecture at the Royal Institution in the same year; and he subsequently followed up the subject by an investigation of the heat developed in the combustion of various articles of food, applying the results in illustration of the phenomena of the exercise of force.

Lastly, Kellner has made some very interesting experiments with a horse at Hohenheim, the results of which were published last year. In one series, the experiment was divided into five periods, the same food being given throughout; but the animal accomplished different distances, and drew different weights, the draught being measured by a horse-dynamometer. The changes in live-weight, the amount of water drunk, the temperature, the amount of matters voided, and their contents in nitrogen, were also determined.

The result was, that with only moderate labour there was no marked increase in the nitrogen eliminated in the urine, but that with excessive labour the animal lost weight and eliminated more nitrogen. Kellner concluded, accordingly, that, under certain circumstances, muscular action can increase the transformation of albumin in the organism in a direct way; but that, nevertheless, in the first line is the oxidation of the non-nitrogenous matters—carbo-hydrates and fat, next comes in requisition the circulation-albumin, and finally the organ-albumin is attacked.

In reference to these conclusions from the most recent experiments relating to the subject, we may wind up this brief historical sketch of the changes of view respecting it, with the following quotation from our own paper published in 1866:[1]—'. . . all the evidence at command tended to show that by an increased exercise of muscular power there was, with increased requirement for respirable material, probably no increased production and voidance of urea, unless, owing to excess of nitrogenous matter in the food, or a deficiency of available non-nitrogenous substance, or diseased action, the nitrogenous constituents of the fluids or solids of the body were drawn upon in an abnormal degree for the supply of respirable material.'

In conclusion, although I fully agree with Voit, Zuntz, Wolff, and others, that there still remains much for both Chemistry and Physiology to settle in connection with these two questions of '*The Sources of the Fat of the Animal Body*' and '*The Origin of Muscular Power*,' yet I think we may congratulate ourselves on the re-establishment of the true faith in regard to them, so far at least as the most important practical points are concerned.

[1] 'Food in its relation to various exigencies of the animal body.'—*Phil. Mag.*, July 1866.

The following Reports and Papers were read:—

1. *Report of the Committee upon the Present State of our Knowledge of Spectrum Analysis (Spectra of Metalloids).*—See Reports, p. 258.

2. *Report of the Committee upon the Present State of our Knowledge of Spectrum Analysis (Ultra-violet Spectra).*—See Reports, p. 258.

3. *An Improved Volumetric Apparatus was exhibited by* J. W. STARLING.

4. *On the Coal Seams of the Eastern Portion of the South Wales Basin and their Chemical Composition. By* J. W. THOMAS.

5. *On a New Mode for the Purification of Sewage. By* P. SPENCE.

The question of the disposal of sewage is still an unsettled one, and is becoming daily more pressing.

To our large towns it is now a most serious matter; the rivers that flow past many of them are assuming the character of pestiferous sewers; fish have ceased to live in them, and are gradually dying out from others; and, excepting where towns are near the sea, the rivers will become nuisances to an extent that will be unbearable.

Many schemes have been tried and some are now in operation, by which sewage has been partially or completely purified; filtration and irrigation can be made to effect the object, but have chiefly been tested in small localities, and they are, I believe, tacitly given up as applicable to large populations.

Precipitation by lime is now practically the mode by which, not purification, but partial clarification is conducted, and by which the demands of the law are not met, but merely evaded. Dr. Angus Smith, one of the Government inspectors under the Rivers Pollution Act, gives as the result of many analyses of lime-effluents, that while the solid sludge of the sewage is precipitated and the liquid is thereby clarified, it still contains nearly all the soluble putrefiable matter, and is really a very impure fluid.

Where, in addition to lime-clarification, subsequent irrigation with the effluent is practicable, it is rendered nearly pure; and where, in connection with lime, salts of alumina are used in sufficient quantity, the water or effluent is pure, limpid in appearance, free from colour, smell, and putridity.

Having been engaged for some years in producing, in a cheap form, a sulphate of alumina suitable for purifying sewage, and which is at the present moment used by nearly all who are purifying by alumina, I have necessarily had my attention directed to the problem of the best mode of precipitation by which the aluminous salt, which is still an expensive substance, could be economised, and the sewage completely purified at the smallest cost. Where alumina is used various other substances have been and are now used in connection with it; these are blood, clay, charcoal, iron salts, and other bodies of more or less efficiency: none of these substances are, I believe, essential to the process, and some of them are probably useless.

Lime is in nearly all cases needful to the efficiency of the aluminous salts, excepting in those where the sewage is decidedly alkaline; but as this condition cannot be depended upon, it may be taken for granted that lime should always be used.

In the new scheme which I shall now describe, I commence on the basis of the lime-process as now conducted, and assume that it is so far useful and is a preparation for real purification, and I propose to take the effluent as it comes

from that process, and by the use of a solution of alumina to effect its complete purification.

In operating upon this clarified lime-effluent, I find two great advantages. The first of these is that the effluent always contains a portion of lime in solution sufficient to decompose the small quantity of aluminous salt which is required. When this salt is added, the lime-effluent, invariably opalescent, generally coloured, and never transparent, at once changes its appearance, the alumina in precipitating unites with the albumen and colouring matters, and in a few minutes coagulates and slowly descends, leaving the fluid transparent, colourless, and free from smell, this effluent or water being now fit for any purpose except potable uses.

The second advantage of this new process is that the precipitate which contains all the alumina of the salt used settles to the bottom of the tanks as a light flocculent body, and can from thence be pumped up into suitable reservoirs, and when we add to it the equivalent quantity of sulphuric or hydrochloric acids requisite for combination, then in the cold and however largely diluted, all the alumina is dissolved, and the same quantity of aluminous salt in solution is formed as was originally used, and after allowing the very small quantity of coloured albuminous residuum to subside, the solution is run into a new quantity of lime effluent, thus using the alumina over and over again, and reducing the cost of the aluminous compound to that of the cost of the acid needful for its resolution.

I have fully verified the facts that all the alumina is in these circumstances thrown down, and that when so precipitated it is again all dissolved without using any excess of acid.

The cost of the process is thus reduced to a very small sum when compared with any mode of purifying now in use. While nearly all the modes which really purify are impracticable, the new plan only requires a small extension of the apparatus where lime-clarification is adopted, and. that process has come largely into use on the ground of its cheapness, while it is only a mitigation of a great evil, yet its cost is not less than 50*s.* to 70*s.* for every million of gallons operated upon, and some of those who are now doing their best with it are threatened with prosecution and probably injunction.

If the new process in such cases were added to it, I estimate that it would not add more than one-fifth to their expenses, and I have no hesitation in giving the assurance that nothing else in sewage-purification will be required when the plan now proposed is fully carried out.

SATURDAY, AUGUST 28.

The Section did not meet.

MONDAY, AUGUST 30.

The following Papers were read:—

1. *On the Refraction-equivalent of Diamond and the Carbon Compounds. By* J. H. Gladstone, *Ph.D., F.R.S.*

It was shown by Mr. Dale and the author, in 1863 ('Phil. Trans.' p. 317), that the specific refractive energy of a substance was a very important property; for it is a constant, little, if at all, affected by changes of temperature, of aggregate condition

or, to a considerable extent, by chemical combination. It is the refractive index -1 divided by the density. It was originally reckoned, both for the theoretical limit of the spectrum according to Cauchy's formula, and for Fraunhofer's lines B, F, & H. But in all subsequent work, the author has calculated the specific refractive energy for the line A, as least affected by dispersion $\left(\frac{\mu\,A-1}{d}\right)$. For purposes of calculation among compound bodies, it is more convenient to adopt what Landolt terms the refraction-equivalent; that is, the specific refractive energy multiplied by the atomic weight $\left(P\,\frac{\mu\,A-1}{d}\right)$.

Uncombined carbon as found in diamond has a refraction-equivalent varying from 4·85 to 5·18; the mean may be taken at 5·0. It has the same value in the large majority of its compounds, such as bisulphide of carbon, cyanogen, sugar, tartaric acid, alcohol, and the whole of the ordinary bodies of the fatty acid series. It was very early observed, however, that there were exceptions, and it is now known that the whole of the bodies belonging to the aromatic series, the terpenes, the pyridine series of bases, cinnamyl compounds, and hydrocarbons which are peculiarly rich in carbon, such as naphthalene, anthracene, &c., give an excessive refraction. This peculiarity, so far as the aromatic bodies and naphthalene are concerned, was sought to be explained in a lecture at the Royal Institution, in March 1877, by the fact that the usual atomicity of the carbon is not satisfied, as illustrated by the graphic formulæ usually employed for this class of bodies.

Brühl has lately published a series of papers in which, by careful experiments, he has confirmed and extended previous observations, and he endeavours to prove that wherever there is a double carbon atom with bonds latent, the refraction-equivalent is raised by about 2·0. This view answers satisfactorily for the great aromatic group, for the allyl compounds, for picoline and its congeners, and for amylene, the refraction-equivalent of which is 1·95 above the normal, although the halogen compounds of ethylene, propylene, and amylene are normal. This theory, however, does not seem equally adequate to account for certain other phenomena. 1st. The essential oils which belong to the $C_{10}H_{16}$ or the $C_{15}H_{24}$ group, have a refraction which is neither 2 nor 4 above the normal, but somewhere between these numbers. 2nd. The cinnamyl compounds, such as the well-known oil of cassia, have an abnormal refraction; cinnamene acetate, $C_{10}H_{12}O$, has a refraction of 85·0, which is 13·4 above the calculated amount, while its isomer, phenyl-ethyl acetate, has only the excess of 6·6 which is usual in phenyl compounds. 3rd. The hydrocarbons, which have a greater number of atoms of carbon than of hydrogen, increase in refraction, with the excess of carbon, at a rate which is far more rapid than the theory will admit of, as will be seen from the subjoined table, in which the last column represents the excess of the refraction-equivalent over that calculated from carbon $=5$ and hydrogen $=1·3$.

Substance	Formula	Refraction-equivalent	Excess
Naphthalene . .	$C_{10}H_8$	76·8	16·4
Anthracene . .	$C_{14}H_{10}$	114·7	31·7
Pyrene . . .	$C_{16}H_{10}$	126·2	33·2

It is a remarkable fact that, whereas the value of the carbon increases rapidly as the proportion of hydrogen diminishes, its value reverts to the normal 5·0 in diamond where there is no hydrogen at all.

The author expressed his belief that the specific refractive energy of a carbon compound is a property which must be taken into account in determining its constitution; and he hoped that some of those chemists who have paid particular attention to the theory of organic chemistry, would take up this line of investigation.

2. *The Position of Agricultural Education and Research in this Country and on the Continent of Europe briefly compared and considered.* By J. MACDONALD CAMERON, *F.C.S.*, *&c.*

PART I.

1. *General View of Chemical Agricultural Education in this country and its hindrances.*

The unparalleled development of almost every branch of manufactures during the past quarter of a century is mainly due to the desire which our manufacturing population have shown to turn to account the discoveries of modern science. A striking instance of this development is found in the dyeing industry. Twenty-two years ago plants, and in some instances animals, supplied man with all the colouring matters necessary for his purposes, but in 1855 Mr. W. H. Perkin, F.R.S., then engaged in one of the laboratories of the Royal College of Chemistry, investigating coal-tar residues, discovered that when these residues were submitted to certain treatment they yielded a beautiful colouring matter which he named *mauve*, and which could be used for dyeing textile fabrics. This discovery encouraged others to take up the researches on the coal-tar colours, as they have been called, which in 1878 culminated in the manufacture of three and a quarter millions sterling worth of these materials. Did our agricultural population but have faith in what science can do for them, and more readily accept its discoveries and conclusions, we should hear less of *depression*, and *protection* would not be so often pointed to as the haven of refuge for what I believe to be largely due to ignorance and incapacity. Yet, in the face of agricultural apathy, chemists pursue their investigations, encouraged by the fact that they are increasing our store of knowledge, and that the day is not distant when their work must be utilised.

There are many reasons for this apathy and opposition to the chemist and his work. 1st. Many of our past chemists lacked a knowledge of practical agriculture. 2nd. The farmer's ignorance of even the most elementary scientific principles involved in his vocation. 3rd. The time necessarily taken up in making field and other experiments from which to deduce principles for the future guidance of the farmer. 4th. The want of confidence between the chemist and the farmer—the farmer thinking that the chemist, when he suggests or assists him, does so with a view to some hidden advantage which may be detrimental to his (the farmer's) interests—this can only be obviated by a better knowledge of each other.

2. *Farmers' Societies and Agricultural Education.*

We have in Great Britain—I omit Ireland in the following calculation as it is well provided with the means of Agricultural Education—in round numbers 255 agricultural societies; and, if we except the good work done by the Royal and Highland and Agricultural Societies, nothing has been done by these 255 societies to encourage and develop scientific agriculture, if we except the prizes given at their respective shows for cattle, breeding, feeding, &c., and a few other exhibits remotely related to agriculture. A very different state of things obtains in Holland for example, where the societies not only hold shows and give prizes, but grant annual subsidies to teachers in elementary schools and other qualified persons to teach the principles of agriculture to their pupils, and during the winter months to audiences chiefly composed of labourers. And what is the result? In this country seven-eighths of the farmers cannot tell the difference between soluble and insoluble phosphate, nor between ammonia and nitrate of soda. In the majority of Continental countries both farmers and labourers enter upon life with an intelligent grasp of the principles involved in their daily work, with the inevitable result that the agricultural resources of these countries are pushed to their utmost limit, and their surplus produce comes pouring in upon us, we wondering how they do it!

3. *Relation of Landed Proprietors to Agricultural Education.*

The proprietors of the land ought to be most interested in its development, and decidedly are to blame for not taking that lead which their social position and territorial influence entitle them to, in initiating every movement having for its object the development of the soil-produce as well as the intelligence of their tenantry. Had they done so the position of scientific agriculture would be a very different one.

Part II.

The facilities for acquiring a knowledge of Scientific Agriculture in this country, and on the Continent.

1. *England:—*

(*a*). The Royal Agricultural College, Cirencester.

(*b*). The Science and Art Department, which encourages agricultural education in its usual way by payment on results and by summer courses of lectures to teachers.

(*c*). The Wilts and Hants Agricultural College, Downton.

This institution, recently established by Professor Wrighton, late of the Royal Agricultural College, to supply to the southern counties education similar to that at Cirencester.

(*d*). The Laboratory of Agricultural Chemistry, 52 Lime Street, London, where a course of lectures with laboratory practice is given in connection with agriculture, commencing in October annually.

2. *Scotland:—*

(*a*). The Chair of Agriculture in the University of Edinburgh, subsidized and supported by the Government and the Highland and Agricultural Society of Scotland.

(*b*). The North of Scotland School of Chemistry and Agriculture, Aberdeen, originally established in connection with the Science and Art Department, but now developing into an independent institution which grants diplomas of its own.

3. *Ireland:—*

The Albert Institution, Glasnevin, Dublin, and several other institutions of a kindred nature, besides about 240 institutions of less importance.

Institutions which encourage Agricultural Education by Subsidies and Prizes.

1. *England:—*

(*a*). The Royal Agricultural Society's Examinations and Scholarships.

This Institution encourages agricultural education by four money prizes of 25*l.*, 15*l.*, 10*l.*, and 5*l.*, and ten scholarships of 20*l.*, tenable for one year.

(*b*). The Society of Arts, by means of examinations and prizes.

2. *Scotland:—*

Highland and Agricultural Society of Scotland.

Like its English neighbour, this Society supports agricultural education by granting 150*l.* per annum to the Chair of Agriculture in Edinburgh University, 10*l.* in prizes to the class, as well as granting ten bursaries of 20*l.* each, and five of 10*l.* each.

3. *Ireland:—*

The Royal Irish Agricultural Society.

As the lines upon which this society works are much the same as the English and Scotch National Societies, I need not give any special account of its work.

Part III.

State of Agricultural Education in the following Countries.

There is a most complete system of agricultural education in the following countries:—Austro-Hungary, Belgium, Holland, France, Denmark, Norway, Sweden, Italy, Switzerland, Germany.

The system of agricultural education in Germany being more complete than that of the other Continental countries, I shall allude to it only.

In the German Empire there are 17 High Schools, or Institutes, 31 Middle, 45 Lower, 49 Agrarian, 5 Meadow, 15 Horticultural, besides 1133 others—such as Winter schools—where the scientific principles of agriculture are taught.

In addition to these schools there were in existence, at the close of 1878, 2,652 agricultural societies distributed over the German Empire, engaged in special agricultural work, besides supporting agricultural education. All these schools have experimental stations attached to them, where the theoretical principles expounded in the class room and laboratory are verified in the field. They are partly subsidized by the Government, and partly by the provinces in which they are situated. See Table No. 1.

Part IV.

Agricultural Research in this Country.

1. General view of its position.
2. Experimental stations.

(A). *England:—*

(*a*). The Experimental Station at Rothamsted. Were it not for the great and important work done at this station by Messrs. Lawes and Gilbert, I fear that I should have little to credit research with in this country. From 1847 to 1880 inclusive, 51 original memoirs have been published on field experiments and experiments on vegetation, and 28 papers and reports on the feeding of animals, utilisation of sewage, &c.

(*b*). The experimental station of the Royal Agricultural Society at Woburn. Established in 1877 to test the value of unexhausted manures, &c.

(*c*). The experimental station at Wickhurst Frant, Sussex—established by the author in conjunction with the Tunbridge Wells Farmers' Club to inquire into the causes of the failure of the hop crop.

(*d*). The experimental station at Oxon-Hoath, Tunbridge—established by W. Nevill Geary, Esq., and the author for a similar purpose, and to check the results of the Aberdeenshire experiments with soluble and insoluble phosphates.

(B). *Scotland:—*

(*a*). The experimental stations of the Highland and Agricultural Society at Harelaw and Pumpherston—established in 1877 for the purpose of obtaining an answer to the various questions constantly cropping up as to the money and other value of the different manures used in raising crops.

(*b*). The experimental stations of the Aberdeenshire Agricultural Association. They are five in number, and were established in 1875 for the purpose of ascertaining the best manure for the turnip crop.

(*c*). The experimental station at Ardross, Alness, Rosshire—established by K. J. Matheson, Esq., younger, of Ardross, and the author, to test the value of the experiments made by the Aberdeenshire Agricultural Association, under different climatic and soil conditions, and to extend scientific agriculture.

It being impossible, in a short abstract like this, to give even an idea of the researches now being conducted in agriculture in the several Continental countries above named, I must, therefore, refer persons interested in the subject to my paper about to be published at length.

Part V.

Concluding Remarks and Suggestions.

Notwithstanding the apathy of the past, progress is certainly being made in agricultural education, and the desire for it is increasing.

In 1876, 150 candidates presented themselves for the Science and Art Department's certificate, of whom 9·4 per cent. failed. In 1880, 3,062, or 200 times more, presented themselves, and of these 21·6 per cent. failed.

The Department should encourage the teaching of the principles of scientific agriculture in elementary schools to a class composed of children in the last year of their compulsory attendance; and no teacher should be considered eligible for such a position who has not the Department's Agricultural Certificate. Further, there ought to be a central school in each parish, where the principles and practice of agriculture should be taught. Such schools might, with good management, be made almost self-supporting; but if not, the deficiency should be made up partly by the State and partly by the parish. Proprietors should take the lead in organising committees to encourage popular lectures, and every effort should be made by them to increase our agricultural knowledge. Every restriction should be removed which at present hampers production: and with institutions to guide our agricultural population, such as I have endeavoured to sketch in the foregoing pages, the producing powers of our soil would be considerably increased, as well as the intellectual resources of those who till it, while, as a consequence, higher aims and aspirations would be held out to the latter.

In conclusion, I have to tender my most sincere thanks to Count Giovanni Gigliucci, Lieut.-Col. Donnelly, R.E.; Professor Wilson, Edinburgh University; the Principal of the Royal Agricultural College, Cirencester; Dr. Gilbert, and other gentlemen for statistical and other knowledge relating to this most important subject.

TABLE I.

SHOWING THE POPULATION, REVENUE, SUBSIDIES GRANTED, PERCENTAGE OF REVENUE, AND AMOUNT PER HEAD OF POPULATION PAID TOWARDS AGRICULTURAL EDUCATION IN THE FOLLOWING COUNTRIES:—

	Population	Revenue	Total Subsidy	% of Revenue	Amount per Head
		£	£		
England and Wales	22,712,266		412		$\frac{1}{100}$ or $\frac{1}{4}d.$
Scotland	3,360,018		562		$\frac{1}{10}$
Ireland	5,411,416		6,069		$\frac{1}{4}$ of a $1d.$
United Kingdom	31,483,700	85,399,000	7,043	·008	$\frac{2}{10}$ of a $\frac{1}{4}d.$
Germany	42,727,360	33,087,529	33,582	·1	$\frac{7}{10}$ „
Holland	3,579,527	9,652,058	9,640	·1	$\frac{1}{2}\times\frac{6}{10}\frac{1}{4}d.$
Austria	35,904,435	39,256,514	14,888	·037	$\frac{3}{10}$ „
Belgium	5,336,185	11,148,483	800	·007	$\frac{1}{10}$ „
Italy	26,801,154	57,023,358	10,048	·03	$\frac{5}{10}$ „
France	36,905,788	108,043,200	5,798	·005	$\frac{15}{100}$ „

TABLE II.

	Total Population	Agricultural Population	Proportion of former to latter	Passed Govnt. Exam. in Agricul. 1879	°/o of Agric. population passed Gov. Exam 1879	Schools for Agriculture	No. of Agricultural population to each school
Scotland	3,360,018	378,609	9 : 1	271	·07	2	189,304
Ireland	5,411,416	902,421	6 : 1	15,699	1·7	240	3,706
England & Wales	22,712,266	2,010,454	11 : 1	340	·01	3	670,151
United Kingdom	31,483,700	3,291,484	10 : 1	16,301	·5	245	13,206
Germany	42,727,360	3,000,000	14 : 1			1,305	2,298

3. *On the Specific Rotatory Power of Cane and Invert Sugar.*
By ALFRED H. ALLEN, *F.C.S.*

The angular rotation produced by a plate of quartz of 1 mm. in thickness is 24 degrees for the mean yellow ray or transition tint. In Soleil's polarising saccharimeter the 24 angular degrees are graduated into 100 divisions, and in using the instrument, a solution of cane sugar is employed of such concentration that a column of 2 decimètres in length shall cause a deviation of exactly 24 degrees, or 100 divisions.

If S be the apparent specific rotatory power of an optically active substance in solution; a the angular rotation observed; l the thickness in decimètres of the solution traversed by the ray of polarised light; and c the number of grammes of solid in each 100 c.c. of solution, the value of S can be found by the following equation:—

$$S = \frac{a}{l \times \frac{c}{100}}$$

It is agreed by numerous observers that the apparent specific rotatory power of cane sugar in aqueous solutions, containing at least 10 per cent. of the solid, is + 73·8° for the transition tint. Substituting this value for S in the above equation, 24° for a, and 2 for l, we obtain—

$$73{\cdot}8 = \frac{24}{2 \times \frac{c}{100}}; \text{ whence } c = 16{\cdot}26.$$

Hence the proper weight of sugar to be taken for use with Soleil's saccharimeter is 16·26 grammes, and not 16·19, 16·35 grammes, or any different weight. If it be contended that either of these alternative quantities is the right one to employ, it follows that + 73·8° is not the correct apparent specific rotatory power of cane sugar.

According to Tuschmidt, Casamajor, and many other observers, a solution of cane sugar which, before inversion, shows a deviation of + 100 Soleil divisions, gives after inversion a negative rotation of 44 divisions at 0° C., decreasing by 1 division for each rise of 2° C., so that the inverted solution will show a deviation of − 37 at 14° C., and − 36·5 at 15° C.

Many writers on the rotatory power of invert sugar have overlooked the fact that inversion causes an increase in the weight of solid matter in the solution, 95 parts of cane sugar yielding 100 parts of invert sugar. This increase of weight ought to be taken into account in calculating the specific rotatory power of invert sugar, which at 15° C. is really − 25·6°:—

$$= \frac{-36{\cdot}5 \times {\cdot}24}{2 \times \frac{16{\cdot}26}{95}} = \underline{-25{\cdot}6.}$$

This number corresponds to a value of − 25·94° for S_j at 14° C., instead of − 25·0, as generally stated. If 16·19 grammes be adhered to as the normal weight of sugar per 100 c.c., the value of S_j at 14° C. becomes − 26·05°, against − 25·0° as usually taken.

If the value of S_j for invert sugar be taken at − 26° (the mean of the above values), and O'Sullivan's figure + 57·6° be adopted as the value of S_j for dextrose, then the specific rotatory power of lævulose at 14° C. is − 109·6°, instead of − 106°, as usually taken.

$$26 \times 2 + 57{\cdot}6 = 109{\cdot}6.$$

To sum up, the corrected values of S_j are as follow:—

	S_j
Cane Sugar	+ 73·8.
Invert Sugar	− 25·6 at 15° C.
Dextrose	+ 57·6.
Lævulose	− 108·8 at 15° C.

The deviation, according to the average of the results of various observers, produced by a plate of quartz, 1 mm. in thickness, is 24° for the mean yellow or transition tint, and 21·66° for the sodium ray. Hence the above values for S_j may be calculated to the corresponding values for S_D, by multiplying these by the factor

$$\frac{21 \cdot 66}{24} = \cdot 9025.$$

4. *On the Identification of the Coal-tar Colours.* *By* John Spiller, *F.C.S.*

Dyers and others who are in the habit of using the coal-tar colours are familiar with a number of chemical reactions by which the members of the series may generally be classified and identified. Differences are remarked in their relative affinities for various sorts of fibres, some colours being taken up freely by silk, others fixing better upon wool, and some few, like saffranin, exhibiting a special affinity for cotton. Again, as with the yellows, great differences are observed when the operator proceeds to work with a free acid or a weak alkali in the dye bath, primrose (naphthalene yellow), requiring the former, but not so phosphine (crysaniline yellow), which demands a neutral or even slightly alkaline bath.

By the study of these conditions, aided by a few characteristic tests, it is often possible to identify colouring matters of unknown or doubtful origin, and it is with the view of extending the number of such readily available tests that I recommend a more frequent appeal to the colour-reactions with sulphuric acid.

For this purpose but small quantities of material are required, a few grains serving to impart a distinct colour to a comparatively large bulk of sulphuric acid, and the resulting indications are in many cases both specific and permanent. Oil of vitriol, which so readily destroys nearly all organic structures, does not carbonise any of the coal-tar colours, or does so only under severe conditions, as at high degrees of heat. Even indigo and madder, although of true vegetable origin, are known to yield up their colouring matters to sulphuric acid, the old processes of dyeing depending upon this fact. In the manufacture of garancine from madder the woody fibre and organised tissues are destroyed by the action of sulphuric acid, whilst the alizarin glucoside survives, and with it Turkey-red goods may be dyed.[1] Instances might be multiplied as proof that colouring matters, both natural and artificial, resist the attack of oil of vitriol, and the large class of sulphonates (Nicholson blues, 'acid roseine,' &c.), may be cited as establishing the fact that colouring matters are not so destroyed, but form combinations with sulphuric acid.

If, then, the body under examination be dissolved in strong oil of vitriol, a colour-test is at hand, whereby useful inferences may be derived as to the nature of the dye, and often its exact identity disclosed. A few direct confirmatory tests may then be applied.

The most remarkable colour-reactions are the following:—

Magdala (naphthalene pink) .	gives a	blue black.
Saffranin	"	grass-green, becoming indigo blue on strongly heating.
Crysöidin	"	deep orange, turning almost to scarlet on heating.
Alizarin	"	ruby red or maroon.
Eosin	"	golden yellow.
Primrose (naphthalene yellow)	.	difficultly soluble, first yellow, and colour discharged on heating.
Crysaniline	gives a	yellow or brown solution of marked fluorescent character.
Aurin	"	yellowish-brown, non-fluorescent.
Atlas orange	"	rose colour, turning to scarlet on heating.
Atlas scarlet	"	scarlet solution, very permanent on heating.

[1] See W. H. Perkin's 'History of Alizarin,' *Journ. Society of Arts*, May 1879.

Biebrich scarlet, R.	gives a	blue-black or deep purple.
" " B.	"	bluish-green.
Aniline scarlet	"	golden yellow, permanent on heating.
Indulin	"	slaty-blue to indigo, according to shade of the dye.
Rosaniline, Regina, and all violets	"	yellow, or brownish-yellow.
Phenyl and Diphenylamine blues	"	dark brown solutions.
Iodine green Malachite green		bright yellow solutions, the former giving off iodine on heating.
Citronine		gives a pale cinnamon or neutral tint.

After vitriol the action of concentrated hydrochloric acid may be next tried, which distinguishes at once between saffranin and Biebrich scarlet, the former giving a violet solution, and the latter being precipitated as a red flocculent powder.

Proceeding in this way, and combining the observations with the dyer's usual test, every one of the substances named can be readily identified, and much time saved in the examination of dye-stuffs.

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5. *On the Density of Fluid Bismuth.* *By* W. CHANDLER ROBERTS, *F.R.S.*, *and* THOMAS WRIGHTSON, *C.E.*

Some time since one of us described the results of experiments made to determine the density of metallic silver and of certain alloys of silver and copper when in a molten state.[1] The method adopted was that devised by Mr. R. Mallet,[2] and the details were as follows:—

A conical vessel of best thin Low-Moor plate (1 millimètre thick), about 16 centimètres in height, and having an internal volume of about 540 cubic centimètres, was weighed, first empty, and subsequently when filled with distilled water at a known temperature. The necessary data were thus afforded for accurately determining its capacity at the temperature of the air. Molten silver was then poured into it, the temperature at the time of pouring being ascertained by the calorimetric method. The precautions, as regards filling, pointed out by Mr. Mallet, were adopted; and as soon as the metal was quite cold, the cone with its contents was again weighed.

Experiments were at the same time made on the density of fluid bismuth, and two determinations gave the following results:—

$$\left.\begin{matrix}10{\cdot}005\\10{\cdot}072\end{matrix}\right\}\text{mean, } 10{\cdot}039.$$

The invention of the oncosimeter[3] appeared to afford an opportunity for resuming the investigation on a new basis, more especially as the delicacy of the instrument had already been proved by experiments on a considerable scale on the density of fluid cast-iron. The following is the principle on which this instrument acts:—

If a spherical ball of any metal be plunged below the surface of a molten bath of the same or another metal, the cold ball will displace its own volume of molten metal. If the densities of the cold and molten metal be the same there will be equilibrium, and no floating or sinking effect will be exhibited. If the density of the cold be greater than of the molten metal, there will be a sinking effect, and if less a floating effect when first immersed. As the temperature of the submerged ball rises, the volume of the displaced liquid will increase or decrease according as the ball expands or contracts. In order to register these changes the ball is hung on a spiral spring, and the slightest change in buoyancy causes an elongation or contraction of this spring which can be read off on a scale of ounces, and is recorded by a pencil on a revolving drum. A diagram is thus traced out, the ordinates

[1] *Proc. Roy. Soc.* vol. xxiii. p. 493.
[2] *Proc. Roy. Soc.* vol. xxii. p. 366 and vol. xxiii. p. 209.
[3] *Journ. Iron and Steel Inst.* No. 2. (1879), p. 418.
[4] Ibid. No. 1. (1880), p. 11.

of which represent increments of volume, or, in other words, of weight of fluid displaced, the zero line or line corresponding to a ball in a liquid of equal density to that of the ball, being previously traced out by revolving the drum without attaching the ball of metal itself to the spring, but with all other auxiliary attachments. By a simple adjustment the ball is kept constantly depressed to the same extent below the surface of the liquid, and the ordinate of this pencil line, measuring from the line of equilibrium, thus gives an exact measure of the floating or sinking effect.

If the weight and specific gravity of the ball be taken when cold, we then have sufficient data for determining the density of the fluid metal for $\frac{W}{W'} = \frac{D}{D'}$, the volumes being equal. And remembering that W (weight of liquid) $=$ W′ (weight of ball), $+ x$ (where x is always measured as a $+$ or $-$ floating effect), we have D (density of fluid) $= \frac{D' \times (W' + x)}{W'}$.

The following table shows the results of six experiments made by the authors in the laboratory of the Royal Mint. The bismuth was kept just above its melting point, and this was ensured by placing pieces of metal in the molten mass which were observed just to melt.

No. of Expt.	Diameter of ball in inches	Weight in Troy ounces including thin stem for attachment	Specific gravity of cold ball including this stem	Floating effect on first immersion in Tr. oz.	Deduced specific gravity of fluid metal	Remarks
1	2	23·33	9·72	1·0	10·13	Bismuth ball in fluid bismuth
2	2·25	33·46	9·755	1·3	10·11	do.
3	do.	33·37	9·757	0·6	9·94	do.
4	do.	33·53	9·774	0·7	9·98	do.
5	do.	22·184	6·99 (Iron)	9·3	9·92	Iron ball in fluid bismuth
6	do.	22·184	7·02 (do.)	10·2	10·25	do.

Mean, 10·055.

Specific gravity of solid bismuth, 9·82.

It will be seen that, considering the difficulties of manipulation, the results are remarkably concordant, and their mean agrees very closely with that obtained by Mallet's method. We venture to think, therefore, that the amount of the change of density of bismuth in passing from the solid to the fluid state may now be considered to be definitely settled.

6. *On Crystals of Mercury.* *By* PHILIP BRAHAM, *F.C.S.*

7. *On a New Process for the Metallurgic Treatment of Complex Ores containing Zinc.* *By* EDWARD A. PARNELL, *F.C.S.*

The presence of zinc in considerable quantity in ores containing lead, copper, and silver, is a great impediment to the extraction of the latter more valuable metals by the ordinary smelting processes, and thus tends to reduce considerably the value of such ores to the smelter. Immense quantities of these complex ores exist in which the zinc (present as sulphide of zinc or blende) is so intimately mixed with the sulphides of other metals that it cannot be separated by mechanical means "dressing"). These ores have hitherto remained unproductive, because the highest price offered for them by the smelter would not be remunerative to the miner. By a peculiar combination, however, of wet and dry processes, such ores

are now profitably treated, all the metals being extracted in a marketable form, including zinc, which was previously entirely lost whenever the working of such ores was attempted.

The process is briefly the following: The ore, having been ground, is calcined in a muffle furnace, so as to convert the sulphides of the various metals into sulphates and oxides. The sulphurous acid produced in this operation is conveyed to leaden chambers for conversion to sulphuric acid in the usual manner. The calcined ore is then agitated with weak sulphuric acid, which dissolves the zinc and most of the copper, while all the lead, silver, and gold remain undissolved in the residue. Sufficient hydrochloric acid is generally present in the sulphuric acid to convert all the sulphated silver into insoluble chloride. Separation of the zinc being then effected by lixiviation, the insoluble portion is smelted for the extraction of its metals in the usual way. The sulphate of zinc liquor thus obtained contains very little iron, provided the ore had been calcined sufficiently to convert all the iron to peroxide. All the copper contained in the liquor is next precipitated by metallic iron or zinc, after which the liquor is concentrated by evaporation and mixed, when it begins to thicken, with a small quantity of finely ground blende (1 eq. of sulphide of zinc to 3 eqs. of sulphate of zinc). After further desiccation this mixture is heated to redness in a muffle furnace when the sulphide and sulphate by mutual reaction become changed to oxide of zinc and sulphurous acid gas ($3\,ZnSO_4 + ZnS = 4ZnO$ and $4SO_2$). The former is in a condition well adapted for the manufacture of spelter by distillation in the usual way; the latter is conveyed to leaden chambers for reproduction of sulphuric acid.

The conversion of sulphate of zinc into oxide of zinc may be effected by other reducing agents than blende. Coal and charcoal may be used for that purpose, but as the sulphurous acid is then mixed with carbonic acid, it is not so well adapted for conversion to sulphuric acid in the chamber process, as the gas derived from the mixture of sulphate of zinc with blende.

The operations here described are now being extensively carried on at the works of the Swansea Zinc Ore Company, near Swansea.

Another sulphate which is easily convertible into oxide in an analogous manner is that of magnesia. Pure wood charcoal should be used as the reducing agent, and the mixture heated to dull redness. The magnesia thus prepared corresponds in density to the variety known as 'heavy' calcined magnesia.

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8. *On a New Process for the Production, from Aluminous Minerals containing Iron, of Sulphate of Alumina free from Iron. By* J. W. Kynaston, *F.C.S., F.I.C.*

In this paper the author gives an account of an investigation undertaken for the purpose of devising a means for the production, on a large scale, of sulphate of alumina so pure that it may be used in the arts for all purposes for which pure soluble alumina is required, and so to prevent the loss of the large quantities of potassa or ammonia and sulphuric acid required in the manufacture of the crystallised alums.

He gives a historical statement of the methods in actual use to produce alum substitutes, and of the attempts that have been made to utilise for this purpose the newly-discovered rich aluminous mineral, Bauxite. The great difficulty in the production of pure alumina salts from this mineral arises from the presence in the ore of a comparatively large proportion of peroxide and some protoxide of iron, which dissolves with the alumina when the ore is attacked with acids.

The author states that he has found that a solution of oxalic acid possesses the power of dissolving the oxides of iron contained in Bauxite without materially attacking the alumina, and gives in detail the mode of carrying out the operations, together with the process adopted for recovering the oxalic acid employed for repeated use for the same purpose. He then states the difficulties in the practical working of any process of purifying Bauxite from iron which involves the repeated

washing of the ore, and goes on to describe some reactions which permit of the separation of dissolved iron from aluminous solutions.

In a solution of alumina obtained by treating Bauxite with sulphuric acid, there is contained iron to the extent of 0·80 to 1·00 per cent., about three-fourths of which exists as peroxide and the remaining one-fourth as protoxide. The iron existing as peroxide is rendered insoluble, and precipitated from the solution by converting it into arsenite by the addition of arsenious acid, and then, by means of carbonate of lime, neutralising any free acid, and at the same time producing in the solution a little tetrabasic sulphate of alumina. Under such circumstances, the whole of the iron existing as peroxide falls out of the solution.

The remaining ferrous iron is then removed by the addition of ferrocyanide of calcium, a reaction which, though so well known, has not hitherto been successfully applied for the purpose, by reason of the difficulty of separating the impalpable precipitate of Prussian blue from the solution.

The author has found that the addition to the blue mixture of a mere trace of either the sulphate of copper or of zinc, induces an aggregation of the previously imponderable particles of Prussian blue, which then rapidly fall out of the solution. This precipitate is collected and washed, and by treatment with lime the ferrocyanide of calcium is regenerated and again used to remove more iron.

The solution of sulphate of alumina now freed from iron is lastly treated with sulphide of calcium to remove the excess of arsenic, and then boiled down until of such a density that it solidifies on cooling. The result is a sulphate of alumina, neutral, practically free from iron, and containing about 16 per cent. of alumina, as compared with 10·83 per cent. contained in the ordinary crystallised potash alum.

A description is then given of the mode of carrying out these reactions in the actual process of manufacture as carried on at St. Helens, and, finally, attention is drawn to the probability of an extensive consumption of sulphate of alumina, in the future, in the process of refining beetroot sugar. A large quantity of potash is contained in sugar from this source, and it prevents the crystallisation of much of the sugar. It has been known for some years that by means of sulphate of alumina potash might be removed from the syrup, but the process has not been extensively adopted by reason of the difficulty of obtaining sulphate of alumina sufficiently pure for the purpose.

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9. *On a New Process for separating Silver from Copper contained in Copper Ores and Reguluses. By* WILLIAM HENDERSON.

The latest literature on this subject seems to award the palm of accuracy and cheapness to Zeir-vogel, who proposes by calculation of reguluses to form in the first place sulphates of iron and copper which are gradually decomposed by further calcination into the state of oxides, leaving argentic sulphate, which stands a much higher temperature undecomposed, and which is soluble in pure water.

The difficulty always remains, in calcining reguluses or ores, to do it in such a way as to convert the whole of the silver into sulphates. To ensure the result with certainty I have called in the aid of a bisulphate, and I have taken bisulphate of soda as the cheapest and as carrying a large proportion of available sulphuric acid. The theory of the process is, that bisulphate of soda cannot be reduced to sulphate by simple fusion, but parts with its second equivalent of sulphuric acid to several metals at a comparatively low temperature. I thus ensure at once, and early in the process, sufficient imprisoned sulphuric acid to make sure that the whole of the silver will be converted into sulphate at the end of the process after the other metallic sulphates are decomposed.

If the reguluses are comparatively free from arsenic and antimony the bisulphate may be at once mixed with them, and the calcination proceed at once, as in the Zeir-vogel process.

For several years I have again and again taken up this subject without successful results; at all events the results were, as a rule, imperfect and no improvement upon those at present in use. In the early part of 1879 my attention was

again attracted by the circumstance that some mines in Central Spain were offered to me which produce copper ores rich in silver and a small quantity of cobalt, and it was desirable if possible to devise some cheap and simple process whereby these metals could be perfectly separated from each other.

A series of experiments led to the adoption of bisulphate of soda for this purpose, which gives for silver very perfect results with reguluses. I have not been so successful with ores, for obvious reasons.

Therefore, on November 3, 1879, I took out a patent, No. 4481 of that year, 'for treating certain ores and reguluses,' and I have since made a good many experiments which, I regret to say, are principally crucible experiments, not having at hand any reguluses rich in silver to work with on a large scale.

My last results are, however, so exact that I venture now to lay them before the Chemical Section of the British Association.

The ore I had to deal with was from Spain, and contained a very large quantity of arsenic, the calcination of the ore leaving a loss of 28 to·37 per cent.

I found in my first experiments with this new process that both arsenic and antimony very much interfered with the results obtained. I therefore continued the calcination until I had arrived at what is technically known as calcined 'dead.' My aim was to produce a regulus of about 50 per cent. copper, and to accomplish this I added a corresponding proportion of the ordinary Spanish pyrites, rich in sulphur, and this produced a regulus containing not more than 1 per cent. of arsenic, but contained besides a small quantity of lead which existed in the Spanish ore I had to deal with.

The regulus as produced gave 285 ozs. 16 dwts. 16 grs. of silver per ton of regulus, and of copper 42 per cent.

In previous experiments I had come to the conclusion that, provided the regulus did not contain much arsenic or antimony, as good and even better results were obtained from the raw regulus. To test this, equal quantities of the same regulus—1st, calcined 'dead'; 2nd, half-calcined, 3rd, raw regulus—each with 20 per cent. of bisulphate of soda, were added. The three crucibles were placed in the same fi~e and calcined at a gradually increasing heat, and finished at a bright red heat when gases had ceased to be given off. This occupied one hour and twenty minutes. The results were as follows:—

					ozs.	dwts.	grs.
1st	silver	soluble	0·7615	per cent. =	248	15	4
2nd	„	„	0·8265	„ =	269	19	20
3rd	„	„	0·8765	„ =	286	6	12

This last result I consider very perfect, and I regret much that I have not been in a position to place before you anything more than laboratory experiments.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *Further Notes on Petroleum Spirit and Analogous Liquids.* *By* Alfred H. Allen, *F.C.S.*

In a paper read before the Section at the Sheffield Meeting, the author described ce.tain tests by which the ordinary 'benzoline' or petroleum spirit of commerce could be distinguished from and approximately estimated when in admixture with coal-tar naphtha or crude benzene.

Extending his researches in this direction, the author now described methods by which the above-named products could be distinguished from the very similar liquid known as 'shale naphtha,' obtained as a secondary product in the manufacture of paraffin wax from bituminous shale.

The following table shows some of the leading distinctive characters of the three liquids:—

——	Petroleum spirit	Shale naphtha	Coal-tar naphtha
Specific gravity .	·690.	·718.	·860.
Boiling point .	55 to 60° C.	55 to 60° C.	80° C.
Action on coal-tar pitch .	Very slight solvent action. Liquid scarcely coloured.	Same as petroleum spirit.	Readily dissolves pitch, forming a deep brown liquid.
Reaction when 3 measures are shaken with 1 measure of fused crystals of absolute carbolic acid .	Liquids do not mix, and remain *apparently* unchanged.	Liquids form a homogeneous mixture.	Miscible in all proportions.

It is evident, therefore, that while shale naphtha resembles the petroleum product in its general physical characters and its slight solvent action on pitch, it is sharply distinguished from it by its reaction with carbolic acid.

The burning oils from petroleum and from shale resemble each other very closely. Neither product is miscible with absolute carbolic acid, but that from petroleum gradually turns the acid violet and ultimately black.

The different behaviour of petroleum and shale naphthas with carbolic acid suggested that they were not quite so similar in composition as is commonly assumed to be the case, and further experiments showed that while petroleum spirit had but little tendency to combine with bromine, and was only with great difficulty acted on by nitric acid, the shale naphtha presented a marked difference in these respects. These facts of course point to a probability, almost amounting to certainty, that shale naphtha contains a large proportion of *olefines* or hydrocarbons of the general formula C_nH_{2n}, while petroleum spirit consists chiefly of *paraffins* or hydrocarbons of the formula C_nH_{2n+2}. Quantitative experiments with nitric acid show that while shale naphtha contains only 15 to 25 per cent. of paraffins, the balance being olefines, in petroleum spirit these proportions are reversed.

The burning oil from shale also consists chiefly of olefines, while in kerosene or petroleum burning oil paraffins predominate.

The following table shows the general composition of the products from shale and petroleum:—

——	Petroleum	Shale
Naphtha . .	At least 80 per cent. paraffins, the remainder probably olefines. Distinct traces of benzene and its homologues.	75 to 90 per cent. of paraffins, the remainder olefines. No benzene or its homologues.
Photogene .	55 to 80 per cent. of higher paraffins, the remainder apparently olefines.	Apparently 60 to 65 per cent. of olefines, the rest paraffins.
Lubricating oil .		Consists almost wholly of higher olefines. No naphthalene.
Wax . . .	Solid paraffins.	Solid paraffins.

2. *On the so-called 'Normal' Solutions of Volumetric Analysis. By* Alfred H. Allen, *F.C.S.*

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3. *On the Determination of the Loss of Heat in Steam-Boilers arising from Incrustation. By* William Thomson, *F.R.S.E.*

On evaporating large quantities of water in small vessels I was surprised to find that some samples evaporated away much more rapidly than others, although the same sizes of flames were allowed to play on the bottoms of each of the vessels; and I afterwards found that the rapidity of evaporation was in the inverse proportion to the quantity of incrustation which had formed on the bottoms; I was further impressed by the small quantity of incrustation which was required to make a great difference in the quantity of water evaporated. Based on this fact, I have constructed an apparatus in which four small vessels are set so that the bottom of each dips into paraffin contained in a large vessel, heated by one lamp from the centre; by this means the same quantity of heat is given to each vessel, and it is evident that on measuring the quantity of water evaporated by each in a given time, the amount of heat lost by the incrustation may be determined.

In the arrangement of this apparatus I use one of the small vessels to evaporate pure distilled water, and the others to evaporate waters to be tested for boiler purposes; these samples are placed in flasks or vessels arranged mouth downwards, on Bischoff's principle, so that the water in the small vessels is always kept at the same height until the whole in the flask is evaporated. When the distilled water is evaporated to a certain point the operation is stopped, and the amount of water left is in each case accurately measured. It is evident that the quantities of the different samples which remain in excess of the distilled water would represent in water the quantity of heat lost by the incrustation produced by a given quantity of any sample.

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4. *On the Identification of the Ink used in writing Letters and Documents as Evidence in Cases of Libel, Forgery, &c. By* William Thomson, *F.R.S.E.*

Most of a large number of inks on envelopes sent to the author by different persons, when tested by reagents, were found to differ from each other to a large extent, whilst no two were precisely similar when minute comparisons were made.

The reagents which I have found to give best results are:—

1. Dilute sulphuric acid.
2. Strong hydrochloric acid.
3. Slightly diluted nitric acid.
4. Sulphurous acid solution.
5. Caustic soda solution.
6. Cold saturated solution of oxalic acid.
7. Solution of bleaching powder.
8. Solution of protochloride of tin.
9. Solution of perchloride of tin.

As an example of the results produced by reagents, some inks when treated, for instance, with sulphuric acid are changed to bright crimson, some to deep red, whilst others become blue, green, violet, or grey, of different shades, and some remain practically unaltered; and when, as sometimes happens, the same or nearly the same colour is produced by one reagent, the colours produced by others are very different.

By testing inks in this way on libellous letters, or in cases of forgery, the ink may, under some combinations of circumstances, possess as much individuality about them as the faces of their owners.

I have found that the same ink when put on different kinds of paper gives pre-

cisely similar results with reagents, and also that the same kind of ink made by the same maker at different times gives different results.

Lastly, persons treat and use inks so differently that although two persons may be supplied with precisely the same ink, yet when it has been in use by them for some time, the character of each may become different, being altered by the user leaving his steel pen in the ink, or by leaving it exposed to the light, or by filling the bottle up with one kind of ink before another kind has been entirely finished, or by mixing with it fluids such as water, beer, wine, &c., when the ink is nearly dried up. Thus, as most people have in their ink-bottles fluids which are very characteristic, the testing of the ink on papers or documents to discover the writer may become of the highest importance, although it is seldom that this mode of investigation is adopted.

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5. *Note on Silver Sulphate. By* Philip Braham, *F.C.S.*

The silver sulphate was shown as brilliant transparent crystals of regular octahedral shape and of high refractive power. They were produced by pouring strong sulphuric acid on a plate of silver, and adding a few drops of nitric acid. At first there was a slight chemical action, bubbles of gas being liberated. In a day or two the whole of the sulphuric acid acquires a deep purple tint, probably due to the formation of some oxide of nitrogen. After a lapse of two to three weeks the purple tint sinks towards the silver, and a slight brown tint can be seen on the surface, the layer of liquid above the silver being colourless. About this period long crystals form, which re-dissolve, and the liquid becomes colourless. In the course of a few days brilliant specks are seen, which develop into perfect crystals; those shown had taken over six months in forming.

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6. *The Effects of Magnesia on Vegetation. By* Major-General Scott, *C.B., F.R.S.*

Not among the least wonderful of the anomalies in the conduct of human beings is the persistence, in opposition even to their own interests, with which they adhere to a prejudice long after it has been overturned by experience. The erroneous views of the effects of magnesia on vegetation afford a notable instance. Eminent cultivators have given their testimony from actual practice of its favourable effects, yet the prejudice continues so strong that farmers will often carry other limes from a long distance, and at a much greater cost, rather than employ those made from dolomite. Its slower absorption of carbonic acid, or some defect in the mode of using it, had given in the first instance an unfavourable impression regarding magnesian lime, and this impression has been handed down from one author to another, and has been accepted by the unthinking agriculturist without question. Instances occur even in which men of science have contributed to the propagation of the error.

Now and again there has been some slight protest against the assumption that magnesian lime had qualities noxious to vegetation, but these protests have produced little effect, and the substance, though known to be an important constituent of plants, has seldom been made a component of manures. Thus Professor Johnston recommends the making of experiments both with caustic and mild or carbonate of magnesia, and states, in 1849, that, 'in consequence of previous recommendations it (carbonate of magnesia) has been tried in numerous experiments by Mr. Gardner at Barochan in Renfrewshire, and by Mr. Main at Whitehill in Midlothian. This was never applied alone by these gentlemen, but always as an ingredient of mixed manures, in which it formed only a small proportion. These experiments, therefore, throw no light upon the special effects of this substance on our different crops and soils.'

Thirty years after this we still find Mr. Jamieson thus writing in the report of the proceedings of the Aberdeenshire Agricultural Association for 1878. Speaking

of the essential ingredients of plants, he says that they 'may benefit or injure plants according to the combination in which they are applied; thus chloride of lime and carbonate of magnesia are said to be plant-poisons, although composed of ingredients which are beneficial in other forms, such as carbonate of lime, sulphate of magnesia, chloride of potash, &c.' And again, 'As to magnesia, it may be put down quite as a neglected substance in manures. Judging from examination of soils its application is called for in many cases more urgently than most of the other essential ingredients.' It is true also that Messrs. Lawes and Gilbert introduced 16·3 per cent. of sulphate of magnesia (=2 per cent. of magnesia) into the mixed mineral manures employed in their experiments at Rothamsted, and small quantities were used in the trials of manures made in 1841 and 1842 in Scotland; but one of the most eminent authorities on the question of manures, M. Ville, whose work has been justly received with much appreciation by agriculturists in America and England as well as in his own country, does not think it necessary to introduce magnesia into manures at all, not because he does not consider it to be an essential element in vegetation, but because, as he states, 'it is found in the soil' 'naturally,' and of course he means in sufficient abundance for the requirements of plants.

How far the accuracy of this opinion is borne out by the facts he cites is, I think, open to question, and I therefore place the whole matter, almost in his own words, before you, and it will form an appropriate introduction to my paper.

M. Ville gives in his work the analysis, by Davy, of six samples of earth from different sources, 'all renowned for their fertility,' and states that 'all six possess the same degree of fertility.' Now Sir Humphry Davy, in his work on Agricultural Chemistry, gives the analysis of three of them, and of these he says that one was from a hop garden, another from a 'good turnip soil, and a third from an excellent wheat soil.' In none of the six samples, excepting that from the 'hop garden,' did Sir Humphry Davy find any magnesia, and in that he found ·7 per cent. of magnesic carbonate (=·33 magnesia). M. Ville gives also the analysis of a soil from Chalons-sur-Marne, by M. Rivot, which showed only traces of magnesia. At the same time they contained, with one exception (which had only ·6 of calcic carbonate), a fair proportion of lime, viz. from 4·7 to 57·2 of calcic carbonate. It is true that in the days of Davy methods of analysis were not so accurate as at present, and that magnesia might have been, and most probably was, present in some of the five samples in which it was not detected or noted by him; but the magnesic element must have been present in insignificant proportion in comparison with the calcic.

At the end of his work M. Ville gives tables for calculating the relative exhaustion of soils under different crops, but in these tables no mention whatever is made of magnesia as an element abstracted from the soil by plants, though it is an undoubted fact that the seeds of peas, beans, rape, and wheat carry off a comparatively large proportion of it. In 100 parts of the seed crop of wheat there are 12 parts of magnesia and only 4 of lime, and in the straw of this plant the quantity of magnesia is about one-half that of the lime, yet M. Ville omits magnesia from his normal manure for cereals, though lime, in the somewhat soluble condition of sulphate, forms nearly one-half of the whole compound recommended for a wheat crop. And this fact appears the more remarkable when we examine the experiments made with the different mineral elements of plants by M. Ville. With reference to these experiments, he says: 'This time a fixed and invariable quantity of nitrogenous matter was mixed with the [calcined] sand [soaked with distilled water] as a constant ingredient, and all the other mineral ingredients were added by turns except one. The experiments were repeated as many times as there were different mineral ingredients, in order that each might be excluded in its turn, the deviation between the crops obtained with the ten mineral ingredients and those in which they were reduced to nine, being taken to indicate the degree of importance of the suppressed ingredients.

. . . .

'Magnesia was submitted to the same method of exclusion. The defects were as disastrous as in the case of potash.

'There are some plants, particularly buckwheat, on which the effects of this

suppression are immediate; on wheat they are manifested a little more slowly, but are still very significant, and when magnesia is excluded from the soil the yield falls to about 123 grains instead of 337.

. . . .

'The suppression of the lime produces a less sensible effect—the yield is then about 307 instead of 337.

. . . .

'Leaving the culture in calcined sand, I extended my investigations to various natural soils.

'On submitting them to the same experimental system we found that . . . . the yield is maintained at the same level as when sulphur, silica, soda, magnesia, iron, and chlorine are added, which explains to you why I did not go further into the effects of those bodies.

'Experience, therefore, shows that the four ingredients—nitrogenous matter, phosphate, potash, and lime—are the only ones that need be admitted into manures.' (Ville, pp. 153-5.)

'I give the name, therefore, of normal manure to the mixture of phosphate of lime, potash, lime, and a nitrogenous material.

'In so doing, I do not intend to deny the utility of the other ingredients; I exclude them from the manure because the soil is provided with them naturally.

. . . .

'If we pass from these fundamental data to the function of each mineral ingredient in particular, the results are neither less expressive or less explicit. The soil being provided with nitrogenous matter as a constant ingredient:—

	wt. of crops.
'With all the mineral matter except phosphate	nil.
" " " potash	138
" " " magnesia	107
" " " soluble silica	123
" " without any suppression	275 to 337.'

—pp. 156–157.

M. Ville's conclusions respecting magnesia, and indeed silica, appear to me to be far from convincing. If the above results can be said to demonstrate anything, they demonstrate that magnesia comes next to phosphate in importance as an element of mineral manures, and, as I shall show eventually, this is not far from the truth. I shall, however, now proceed to show that there are experiments recorded indicating that considerable advantage is derived by adding to very many soils more magnesia than they naturally contain, and we shall find also important testimony to its value where it naturally occurs.

Sir Humphry Davy in opposing the common notion of the noxious qualities of magnesian lime, and accounting for this prevalent and erroneous opinion, states that:—

'Magnesia in its mild state, *i.e.* fully combined with carbonic acid, seems to me to be always a useful constituent of soils. I have thrown carbonate of magnesia upon grass, and upon growing wheat and barley, so as to render the surface white, but the vegetation was not injured in the slightest degree; and one of the most fertile parts of Cornwall—the Lizard—is a district in which the soil contains mild magnesian earth. The Lizard Downs have a short and green grass which feeds sheep, producing excellent mutton, and the cultivated parts are amongst the best of corn lands in the country.' ('Davy's Agri. Chem.' pp. 299–300.)

Davy also found that wheat grew better in a soil with which he had mixed peat and magnesia than in either the 'pure soil,' or the pure soil and peat alone. It grew very well in the pure soil, and nearly as well as with magnesia in the mixture of peat and pure soil, but peat often contains a notable quantity of magnesia. The ashes of the brown herbaceous peat in the neighbourhood of Troyes contain 14 per cent. of magnesia, and those of a peat from the frontiers of Bavaria and Bohemia contain 3·5 per cent of it. Gelatinous silica and sulphate of lime are also frequent constituents of peat, and the fact, therefore, that the mixture of peat

and pure soil gave better results than the pure soil, derogates little, if at all, from the evidence of improvement given by magnesia.

Again, Morton in his 'Encyclopædia of Agriculture,' in opposing the erroneous opinions current against the use of magnesian lime, mentions that 'In the neighbourhood of Castellamonte and Baldissiro, the most luxuriant vegetation is met with on a soil which contains a very large quantity of magnesia, and in our own country many very fertile soils are found in the New Red Sandstone formation, which likewise is rich in magnesia.'

John Donaldson, the author of a 'Treatise on Manures,' having been engaged in the cultivation of land in the immediate neighbourhood of Breedon Magnesian Rock in Leicestershire, says:—'I had occasion to use considerable quantities of lime, and consequently had a fair opportunity of proving the quality of that rock for agricultural purposes.' On two fields (the farm he tells us had been most miserably scourged and impoverished by the preceding tenants) he spread the magnesian lime at the rate of 200 bushels an acre, and in another field 'a double allowance of lime, or 400 bushels per acre . . . . which, being both a large quantity and in a caustic state, would test the supposed noxious quality of the lime. In every case the green crops were good; . . . one field was sown with barley, which yielded a most beautiful crop of 7½ quarters per acre, and the other produced 5 quarters of wheat, both very great crops when the exhausted state of the land was considered.

When the wheat braided in November, the space which had got 400 bushels to an acre immediately showed a great superiority, which continued to the day of reaping, being much thicker on the ground, of a darker colour throughout the winter, and afforded more produce as the shocks were thicker on the ground, and discernible on the first view of the field. The succeeding crop of hay on that space showed an equal superiority, and for several years in succession.

'The same lime was used in the same quantity, of 200 bushels to an acre, and with the same beneficial results, without a single exception. On the headland where the lime lay, and where any damage might have been expected, there grew a very close and heavy crop of beet, with roots not equalled in size and weight. Many eminent cultivators join in the same opinion of magnesian lime derived from actual practice.' ('A Treatise on Manures,' by J. Donaldson, pp. 157–8.)

This experiment is very instructive and conclusive, for on comparing the results obtained with the constituents of each of the various crops, it will be observed that the beneficial results were in proportion to that of the magnesia which the ash contains. Though the green crops were good, it is specially mentioned by Donaldson that the space which had the double allowance of magnesian lime '*showed no difference in the turnip crop*.'

The following table, extracted from 'How Crops Grow' (Eng. ed. by Church and Dyer), gives the percentage of magnesia and lime in the ashes of the crops alluded to:—

	Magnesia	Lime
Turnips (mean of 3 sorts)	2·9	11·2
Hay	4·9	11·6
Barley straw	2·4	7·6
„ seeds	8·3	2·5
Beet	8·9	6·3
Wheat straw	2·6	6·2
„ seeds	12·2	3·1

We here see that Donaldson's results are exactly in accord with what would have been predicted from a consideration of the mineral constituents of the different crops. The turnip, containing the smallest proportion of magnesia, is not benefited by the presence in the soil of a double proportion of that substance; probably the 200 bushels to the acre of Breedon lime supplied quite enough lime and more magnesia than was necessary for that crop: but in the case of wheat, where for the formation of the seed a very large supply of magnesia was necessary, the dose of 200 bushels to the acre was insufficient to enable the roots to find the requisite amount of magnesia for the full development of the crop, and yet, if, in this matter, we are to follow M. Ville's prescription, all the soils naturally contain enough

magnesia to supply all the wants of wheat, though analysis shows the presence of mere traces of it only, or none at all. Mr. N. Whiteley, land surveyor, the author of a treatise 'On the application of Geology to Agriculture,' whilst receiving as well founded the common prejudice against the magnesian lime in its hot state, does full justice to the fertilising effects of magnesia in its mild condition. He says, speaking of land near St. Kevern, in Cornwall: 'If we seek for a soil theoretically perfect it may be found in this formation. The large amount of magnesia which this fruitful soil contains (9 per cent.) is worthy of observation.' Of the magnesian limestone formation he says that 'much of it is thin, light, and dry,' and 'we are prepared therefore to meet with a soil of medium quality; much of the soil on the magnesian limestone is in arable culture, but from Standrop to Darlington the soil may be considered the best and richest grazing land in the North.' Strong confirmation of the views I am seeking to establish is to be derived from a consideration of the cases of soils, which are either abundantly supplied with, or are very deficient in magnesia.

In the following table are given the proportions of lime and magnesia found in both fertile and barren soils. I give the lime as well as the magnesia, because that substance is considered, very rightly, a most important ingredient of manures, although usually its proportion in soils is considerably in excess of the magnesia:—

PROPORTION OF LIME AND MAGNESIA IN 1000 PARTS OF VERY FERTILE AND FERTILE SOILS.

	Exceptionally fertile						Fertile			
	1	2	3	4	5	6	7	8	9	10
Lime	26·0	9·3	12·6	61·5	12·29	42·1	12·9	7·4	5·3	5·6
Magnesia	9·5	11·6	8·8	8·8	10·82	6·1	5·7	5·3	4·9	3·1

No. 1 is from the analysis of the celebrated black earth of Russia. This remarkable soil is 'the finest in Russia, whether for the production of wheat or grass.' It nourishes, on 60,000 square geographical miles, a population of more than twenty millions of souls, and yet 'exports upwards of fifty millions of bushels annually.' This very properly stands first in my table, as it contains a very large amount of magnesia, and is the most fertile, probably, of any which the table includes.

No. 2. From an analysis by Sprengel of the soil of Nebstein, near Olmutz in Bavaria, which had been cropped in 1847 for nearly 160 years successively 'without either manure or naked fallow.'

No. 3. By Boussingault, a soil from Calvario near Tacunga, Ecuador, South America. It 'possesses extraordinary fertility.'

No. 4. 'A very fertile alluvial soil from Honighpolder,' analysed by Sprengel; no manure has ever been applied to it. The subsoil contains to a great depth the same composition as the surface soil.

No. 5. Soil from Midlothian, analysed by Dr. Anderson. It produces excellent wheat.'

No. 6. From an analysis by Sprengel of a very fertile alluvial soil in East Friesland formerly overflowed, but which had been in 1863 cultivated for sixty years with corn and pulse crops *without manure.*

Nos. 7, 8, 9, 10. From soils at Gottingen, from near Hanover, from Alt-Arenberg in Belgium, and from a virgin soil on the banks of the Ohio respectively. The analyses are by Sprengel.

I do not, of course, assume that the fertility of these soils is due entirely or chiefly to the magnesia they contain; the black earth of Russia, for instance, contains also more than 2 per cent. of nitrogen; nor do I suppose that in very many cases the addition of magnesia where the proportion of it is less, cannot be dispensed with; but I do say, seeing the disastrous effects which accompany its absence, as shown by Ville, the question merits the serious attention of agriculturists. This will be more apparent from the following table of

BARREN SOILS SHOWING THE PROPORTION OF LIME AND MAGNESIA IN 1000 PARTS OF SOIL.

	11	12	13	14	15
Lime . . .	·96	·01	traces	2·9	3·2
Magnesia . .	traces	traces	·12	·7	1·3

No. 11. Refers to a soil which Dr. Sendtner characterises as the most sterile soil in Bavaria.

Nos. 12 and 13. Soils from the neighbourhood of Friesland, also barren.

No. 14. A very barren soil from Luneberg. This soil is wanting in many other elements besides magnesia, and is probably too rich in iron.

No. 15. Also from Luneberg, analysed by Sprengel, as also was the case with the three preceding numbers. Here again I deprecate the supposition that I hold the barrenness of these soils to be solely, or even principally, due to the absence or scarcity of magnesia. Many of the other constituents of plants, not considered by Ville as essential to a manure, are also wanting, as well as some that he deemed to be indispensable.

Probably the opinion of Dr. Liebig may carry with it more weight with the generality of persons than any of the foregoing evidence in favour of making a more extended use of magnesia in manures. In his 'Natural Laws of Husbandry' (pp. 257–8), he says, with reference to guano, the best probably of manures now in the market: 'If we compare the composition of the ashes of various seeds we at once see that the incombustible constituents of guano do not altogether replace the soil constantly carried off in the seeds.'

'In 100 parts of seed-ash are contained:

	Wheat	Peas and Beans	Rape
Potash	30	40	24
Lime . . .	4	6	10
Magnesia . . .	12	6	10
Phosphoric acid . .	45	36	36

whereas guano ash contains in each 100 parts:

Potash	1·56 to 2·03
Lime	34·0 to 37·0
Magnesia	2·56 to 2·00
Phosphoric acid	41·0 to 40·0

'The principal difference between the ash of guano and that of those seeds lies in the deficiency of potash and magnesia in the former. Agriculturists are generally agreed about the necessity of potash for vegetation, and that a supply is required by fields poor in that ingredient, or drained of it; but the question as to the importance of magnesia for seed-formation has not, as yet, met with the same attention, and special experiments in this direction would be very desirable.

'The fact that much more magnesia is found in the seeds than in the straw unmistakably shows that it must play a definite part in the formation of the seed, which might, perhaps, be ascertained by a careful examination of seeds of the same variety of plants containing different amounts of magnesia. It is a well-known fact that the seeds of the several species of cereals, having the same proportion of nitrogen, do not always contain the same nitrogenous compounds, and it is possible that the nature of the latter may, in the formation of the seeds, be essentially influenced by the presence of lime or of magnesia, so that the difference in the proportion of both of their alkaline earths may have a certain connection with the presence of the soluble nitrogenous compounds (albumen and casein), or of the insoluble gluten or vegetable fibrine.'

To pursue this subject further in the direction indicated by Liebig is a task for which I feel myself unequal; but it encourages me to examine narrowly the records of experiments in which magnesia has been made an element of manures, or has been tried alone, or in conjunction with an acid.

Of experiments made with magnesia alone I know of no further instances of a definite and reliable kind than those of Donaldson, above quoted; but concerning experiments with sulphate of magnesia, both alone and combined with other constituents, there are records to which I can refer for further proof of my argument.

Before doing so, however, I wish to call attention to a fact which has a considerable bearing on the case. Both Liebig and Ville hold that farm-yard manure—excellent manure as it is—must be supplemented with mineral substances if full value is to be given to it, and that additional phosphoric acid is necessary to make all of its nitrogen available for plant life. Now, in 100 parts of farm-yard manure there is less than ·14 per cent. of magnesia, and of its mineral constituents the magnesia forms only 1·7 per cent. Donaldson tells us 'the quality of earthy composts and of farm-yard manure is prodigiously improved by a mixture of seaweed. . . . During the seasons of the seaweed coming on shore the farmers have heaps of dung or soil in readiness to receive the immediate benefit of the "wrack," and these heaps, along with any lands which may be in a state fit to receive it, afford a ready application of this invaluable article. Farm-yard manure for turnips is improved by it almost beyond description, and never fails to vindicate the expectations of its effects.' (Donaldson, p. 123.)

Now, what are the components of the ash in seaweed? No less than from 7 to $20\frac{1}{2}$ per cent. of magnesia are found in different kinds of it, and the ashes of the seaweed at the mouth of the Mersey contain upwards of 15 per cent. No doubt in the growth of the turnip crops the advantage is largely derived from the great amount of potash the seaweed contains, but of this substance the ash of dung itself yields upwards of 9 per cent., whereas it yields only, as stated, 1·7 per cent. of magnesia. In the ash of dung, therefore, $\frac{\text{potash}}{\text{magnesia}} = \frac{5\frac{1}{3}}{1}$; in that of the turnip $\frac{\text{potash}}{\text{magnesia}} = \frac{8}{1}$. In seaweed it $= \frac{2\frac{1}{2}}{1}$; it is reasonable, therefore, to suppose that the turnip, if manured with seaweed as well as dung, derives more of the benefit from the magnesia added by the seaweed, than from the potash thus supplied.

We will now proceed to examine some of the experiments made in 1842, and reported by Professor Johnston, which have been already briefly referred to.

Results of Experiments with Sulphate of Magnesia.

1. On Yellow Turnips, by Mr. McLean, Braidwood, Midlothian, 1842.

Farmyard manure, 30 carts	produced, per acre,	24 tons.
" " with $\frac{1}{2}$-cwt. of sulphate of magnesia mixed with it .	" "	25 "

Or the increase gained by $\frac{1}{2}$-cwt. of sulphate of magnesia was 4 per cent.

2. On Yellow Turnips, by Mr. Fleming, Barochan, Renfrewshire, 1842. Variety, 'Early Liverpool.'

Nothing, 1st plot	11·4.
" 2nd plot	12·85.
Sulphate of magnesia, 1 cwt.	14·85.

Here 1 cwt. of sulphate of magnesia alone gives an increase of upwards of from 12 to 30 per cent. (mean, 21 per cent.); but as the sulphate of magnesia was not tried in duplicate, less reliance can be placed on this experiment.

3. On Potatoes, variety 'Early Americans,' carried out by Mr. Fleming, Barochan, in 1842.

Intended to test the comparative advantage of sulphate of magnesia when applied as a top dressing to the young plant, and when mixed with the manure at the time of its application.

No.	Description of manure	Quantity of manure per acre	Produce in tons per acre
As Top Dressing.			
1	Nothing but dung	40 c. yards	12·75
2	Sulphate of magnesia	$1\frac{1}{2}$ cwt.	13·25
3	Sulphate of soda	2 ,,	12·75
4	Nitrate of soda	$1\frac{1}{2}$,,	16·0
5	Nitrate of soda Sulphate of magnesia	1 ,, 1 ,,	22·5
Manure mixed with dung at time of planting.			
6	Farmyard dung alone	35 c. yards.	8·75
7	Sulphate of magnesia	2 cwt.	11·35
8	Sulphate of soda	2 ,,	8·00

These results are very interesting. It might be supposed that the increase in the crop was due to the sulphuric acid, and not to the magnesia; but, inasmuch as sulphate of soda gave no advantage, the effect is plainly not due to the sulphuric acid, unless we suppose the soda to have been injurious, which is not likely to have been the case. An increase of sulphate of magnesia appears also to improve the crop. When $1\frac{1}{2}$ cwt. of the salt was used, as a top dressing, with the dung, the increase was only 4 per cent.; but when 2 cwt. was used with the dung, at the time of planting, the increase was close upon 30 per cent. The result of this experiment appears, moreover, to confirm the view that the mixture of the ashes of sea-weed and dung derives no unimportant advantage from the quantity of magnesia thus introduced into the plant.

4. On Clover and Rye Grass cut for hay by Mr. McLean, Braidwood, Midlothian, 1842.

Nothing	gave	125 stones per acre.
Sulphate of magnesia, $1\frac{1}{2}$ cwt.	,,	290 ,,
Gypsum, 3 cwt.	,,	200 ,,

Here the use of $1\frac{1}{2}$ cwt. of sulphate of magnesia gave the enormous increase of upwards of 130 per cent., whilst 3 cwt. of gypsum (sulphate of lime) gave an increase of 60 per cent. only. It will be of interest at this point to refer to the composition of the mineral constituents of the turnip, potato, clover, and hay, as respects the proportions in them of lime and magnesia, for we shall then see that the advantage gained by the crops experimented on has been in general accordance with what might have been expected from the components of their ashes. I have given also the percentage of sulphuric acid for reasons stated below.

Percentage of Sulphuric Acid, Lime, and Magnesia in the Ashes of

	Sulphuric Acid	Lime	Magnesia
Turnips, the bulbs	13·60	13·60	5·34
,, entire plants	12·52	23·27	3·09
Potatoes, tubers	13·65	2·09	6·28
,, entire plants	12·52	13·11	5·55
Clover	3·33	32·80	8·40
,, rye-grass hay	3·25	6·50	4·01
,, ,, seed	3·24	19·24	5·51

The entire plants of the turnip and potatoes require in the ash 3·09 per cent. and 5·55 per cent. of magnesia, and clover and rye-grass crops (taken in the average proportion of the ashes of their respective crops, viz. 400 lbs. to 220 lbs. per acre,)

require 7·3 per cent. of that substance. The advantage gained by the use of sulphate of magnesia, as shown by these experiments, was:—

		Magnesia in Ash being
For Turnips	$15\frac{1}{3}$ per cent.	3·09
For Potatoes . . .	30 ,,	5·55
For Clover and Rye Grass .	130 ,,	7·3

If this coincidence is accidental it is extraordinary. Another point to which I wish to call attention is the fact that the advantage gained is manifestly largely due to the magnesia, and not to the sulphuric acid only; for where the advantage was the greatest by far, the sulphate of lime did not produce an equivalent effect, though the 3 cwt. of calcic manure carried to the soil upwards of six times the amount of sulphuric acid that the $1\frac{1}{2}$ cwt. of the magnesic salt supplied, and though the latter is far more soluble than the former, gypsum is sufficiently soluble for all the requirements of plants.

A third point remains for remark, and that is the relative effect produced on potatoes in the above experiments of Mr. Fleming, of Barochan, by the use of dung No. 1, of sulphate of magnesia No. 2, of sulphate of soda No. 3, of nitrate of soda No. 4, and of a mixture of nitrate of soda and sulphate of magnesia No. 5. A comparison of these results can leave little doubt in the mind of the immense value of magnesia as an ingredient of a manure for potatoes. By the addition of 2 cwt. of sulphate of soda to the dung no advantage was gained; when $1\frac{1}{2}$ cwt. of nitrate of soda was added to the dung, the extra supply of nitrogen in its nitric acid increased the produce 30 per cent.; but when 1 cwt. of sulphate of magnesia was added to the dung, together with 1 cwt. only of nitrate of soda, the amount of produce rose upwards of 76 per cent. upon what was given by dung alone. Moreover, it is quite clear that as the $1\frac{1}{2}$ cwt. of nitrate of soda alone gave an increase of only 30 per cent., and when sulphate of magnesia was added to the manure, the nitrate at the same time being reduced by 50 per cent., the produce rose to 76 per cent., more than one-half of the advantage was due to the sulphate of magnesia. I have before shown and my conclusions are confirmed by these experiments, that the benefit is chiefly attributable to the magnesia, and not to the sulphuric acid combined with it. There is, indeed, one other possible supposition at variance with this conclusion, viz. that the $1\frac{1}{2}$ cwt. of nitrate of soda was too large a quantity to use per acre; but all experience contradicts this idea.

The following are the results recorded by Professor Johnston of the experiments on cereals, as far as they affect our investigation. The quantities of manure and the crops are, per acre:—

With Barley, Common White.

Nothing	gave 3400 lbs of straw and	47·25 bushels of grain.
$1\frac{1}{2}$ cwt. sulphate of soda $\frac{1}{2}$,, ,, magnesia	,, 3928 ,,	54·9 ,, ,,

With Oats, 2nd crop after old lea, the Manure applied as top dressing two months after sowing.

Nothing	gave 2896 lbs. of straw and	54 bushels of grain.
16 cwt. rape dust	,, 2592 ,,	44·96 ,,
1 cwt. sulphate of soda	,, 2792 ,,	38·56 ,,

With Spring Wheat after Turnip.

Nothing	gave 4056 lbs. of straw and	47·68 bushels of grain.
16 cwt. rape dust	,, 4600 ,,	51·05 ,,
1 cwt. sulphate of soda	,, 3864 ,,	38·00 ,,

With Winter Wheat as top dressing.

Nothing	gave 2560 lbs. of straw and	24·93 bushels of grain.
84 lbs. sulphate of magnesia 5 cwt. rape dust	,, 3200 ,,	28·4 ,,

As the above crops were not the same, and the quantities of manure employed differed and were applied at different times, no exact results may be deducible from the above trials; but as the experiments were all with cereals, we are able to draw general conclusions from them, which are not unimportant, as to the effects of magnesia as a manure, and

First.—As sulphate of soda, when used alone, proved in each case prejudicial, we may assume that at least it did not materially assist the result when mixed with rape dust or sulphate of magnesia.

Secondly.—As rape dust, when used alone, gave only a certain increase to the crop, any further increase when used with sulphate of magnesia must be due to the influence of the latter substance, and

Thirdly.—As rape dust used alone with oats *decreased* the crop of grain 16·6 per cent., and with spring wheat only increased the crop of grain by 7 per cent., whereas when used in conjunction with 84 lbs. only per acre of sulphate of magnesia (=13·6 lbs. of magnesia), as a top dressing with winter wheat the increase rose to nearly 16 per cent., it is reasonable to suppose that some portion—indeed a considerable portion—was due to the influence of the sulphate of magnesia, small as it was, and not to the rape dust as a single agent. So far as the rape dust improved the result it may be supposed to be attributable to the influence of the magnesia, to which substance Liebig, as we have seen, assigns a very definite part in the formation of the seed.

It must be borne in mind in considering the question, how far a soil is likely to be improved by an increase of the amount of magnesia in it, that crops remove from the soil the greater portion of their mineral constituents within a short space of time as compared with the whole duration of the existence of the plants, and that, therefore, it must be of the greatest moment that they should be able to gather them from the soil within this period. After a certain time a cultivated plant advances little in size and weight, although great changes occur in the distribution of its constituents.

Liebig says, with manifest truth: 'As a soil may contain far more potash, or magnesia, or lime than the crop may require, yet, being diffused through a large quantity of earth, the roots may be unable to collect the ingredients fast enough to supply the growing wants of the plant—to such a soil it will be necessary to add a further portion of what the crop requires.'

The last experiments to which I shall refer are those of Dr. Pincus, of Insterburg, which Liebig characterises as most important, both on account of the careful manner in which they were conducted and the conclusions drawn from them. Three plots of ground were selected lying close together, each of about five-eighths of an acre in extent, from the middle of a large clover field. The clover crop had a very promising appearance and the plants were then about one inch high; one of the plots was manured with 1 cwt. of gypsum, the second with the same quantity of sulphate of magnesia, and the intervening plot was left unmanured. When all were in flower the clover was mown, and the following were the results:—

	Per $\frac{5}{8}$ acre.
Without manure	21·6
With gypsum (sulphate of lime)	30·6
With sulphate of magnesia	32·4

Or the gain with the use of the magnesic salt as a manure was just 50 per cent. It is to be observed that the stems were developed by both the sulphates much more than the leaves and flowers. The experiment also showed that there was no proportion between the quantities of sulphuric acid found in the crops and in those supplied by the two sulphates. The quantity of sulphuric acid in the two sulphates was 31·12 lbs. in the sulphate of magnesia, and 44·18 in the sulphate of lime, which is about 6 : 8·8. The quantities of sulphuric acid in the two crops obtained severally by sulphate of lime and sulphate of magnesia were as 6 : 8; and on the plot manured with sulphate of magnesia, which had received less sulphuric acid than the gypsum plot, the amount of vegetable matter was 8 per cent. higher than on the latter.

Liebig, from experiments made on arable soils, came to the conclusion that dressing a field with sulphate of lime makes the magnesia in the soil soluble and

distributable. An experiment made to test this conclusion showed that the contact of arable earth with the solution of sulphate of lime is attended by an actual substitution of magnesia for lime. If this notion be correct, it points to a cheaper mode of supplying magnesia to the soil than to add sulphate of magnesia to manures, for it follows that the use of gypsum in conjunction with comparatively small doses of magnesian lime will effect all that is necessary in cases in which heavy carriage interferes with the use of an abundant supply of that substance.

In conclusion, though any one of the above proofs of the value and importance of magnesia in a manure may not carry conviction with it, yet taken altogether the evidences are overwhelming against the notion that soil naturally contains so much magnesia that an extra supply will be of little or no benefit. Moreover, there are strong grounds for supposing, as we have already indicated, that magnesia, like phosphoric acid, is not only an essential ingredient of plants, and aids in their nutriment, but that it determines also the beneficial action of the other ingredients.

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7. *On the Action of Oils on Metals.* *By* William H. Watson, *F.C.S.*

Referring to a previous paper read by him at the last Plymouth meeting, on the action of oils on copper, the author now makes the comparison between the action of various oils on copper and on iron, and shows that they act very differently on the two metals. He finds in several instances that those oils which act little on copper act *proportionately* greatly on iron, while those which act little on iron act greatly on copper. Thus linseed and olive oils, which act the most on copper, act much less than either sperm or colza on iron. Almond oil also acted very slightly on iron (in fact, with the exception of paraffin and the special lubricating oil, it had the least action of any of the oils examined), but on copper the action was great.

Five hundred-grain measures of each oil were poured over a piece of bright sheet iron, exposing 8 square inches of surface. After being kept thus exposed in beakers during twenty-four days, the appearances were noted and determinations made of the iron in the oils, with the following results :—

Neatsfoot (English) oil	0·0875 grain.
Colza oil	0·0800 „
Sperm oil	0·0460 „
Lard oil	0·0250 „
Olive oil	0·0062 „
Linseed oil	0·0050 „
Seal	0·0050 „
Paraffin oil	0·0045 „
Almond oil	0·0040 „
Special lubricating oil	0·0018 „

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8. *On Bleaching Powder Residue.* *By* Frederick W. Hodges, *F.I.C., F.C.S. Berlin.*

Preliminary Investigation.

Persoz,[1] in describing the preparation of a solution of chloride of lime for bleaching purposes, has laid great stress on the necessity for allowing the solution to rest, so that the insoluble matters may subside; as, he says, without this precaution great risk is run in employing a solution which is not perfectly clear and transparent, as he has perceived that the small insoluble particles held in suspension are liable to find their way into the interstices of the fabrics being bleached, and on these being afterwards passed through the acid bath these particles are decomposed, and chlorous and hypochlorous acids are liberated, which burn the goods, producing holes in numerous places. This, he says, is of frequent occurrence in

[1] *Traité théorique et pratique de l'Impression des Tissues.*

the bleaching of muslin. Persoz does not agree with M. Edouard Schwartz, that this damage to the goods, perceived by the former, arises from small bubbles of chlorine gas, as he determined by direct experiment that muslin in a wet condition could be submitted to chlorine gas for a considerable period without undergoing sensible alteration; but he believed that there existed in the insoluble portion of the bleaching powder of commerce a basic compound of unknown composition, and that to this compound the destruction of the fibre was due. In proof of this, he mentions that on washing a sample of bleaching powder till he could no longer detect any bleaching agent, he obtained a residue containing more or less lime and carbonate of lime, and on the addition of hydrochloric acid to this residue there was evolved a most energetic oxidising agent. He also relates that, on spreading this residue on woven fabrics, and afterwards passing these fabrics through an acid solution, holes were produced in them in many places. Now, as these statements of Persoz are considered correct by many eminent chemists, though they have, as far as could be ascertained, not been verified, and as they are, if correct, of serious importance to the bleacher, Professor Lunge suggested the advisability of submitting the matter to careful investigation, and with that object a series of experiments was undertaken, the results of which are here described:—

The investigation was divided into several parts.

(1.) Could bleaching powder be deprived by washing with cold or tepid water of its power to act on iodine and starch paper; and if so, how much water is required for a definite weight of powder?

(2.) What is the percentage of residue after the complete extraction of the bleaching agent?

(3.) If the residue in which iodine and starch paper failed to detect any bleaching agent would evolve any oxidising body on the addition of an acid?

(4.) What is the effect of the residue with the addition of an acid on textile fabrics?

(5.) What is the percentage of chlorine left in the residue of bleaching powder which has been dissolved for the preparation of a bleaching solution by Irish bleachers, and what effect has this residue with and without an acid on fabrics?

The apparatus employed for the solution of the first question were merely (1st) glass funnels, into which fitted small cones of De La Rue's parchment paper, over which were placed cones of Swedish filter paper; the funnels were now attached to Bunsen's filter pump bottles, and the filter paper allowed to become thoroughly dry; (2nd) newly-prepared iodine and starch paper.

Three samples of bleaching powder having been reduced to a uniform degree of fineness were examined for the percentage of chlorine, with the following results:—

1st. English bleach . . .	contained	35·399	per cent.	chlorine.
2nd. Swiss "	"	35·760	"	"
3rd. Specimen prepared in laboratory	"	43·180	"	"

The sample No. 3, which contained such a high percentage of chlorine, was prepared by a student of Professor Lunge's, and an account of its manufacture will, I believe, after some time be published.

Having weighed carefully 10 grammes of each sample, they were placed in the funnels, and 100 c.c. of distilled water, at 15° C., was poured over each. The pumps were then set in action, and when all the water had completely passed through, each filtrate was examined for chlorine by Penot's arsenious acid process, after which the filter bottles, having been thoroughly washed and dried, another 100 c.c. of distilled water was added to each 10 grammes, and the pumps again set in action. This operation was repeated until each sample had been washed with 600 c.c. of distilled water, and though the filtrates still gave a most decided reaction with the iodine and starch paper, almost all the chlorine had been washed out, as can be seen by the following table:—

	English B. % Chlorine.	Swiss B. % Chlorine.	Laboratory B. % Chlorine.
With 1st 100 c.c. extracted	14·0	13·72	34·39
„ 2nd „ „	10·900	11·60	3·19
„ 3rd „ „	6·000	5·91	3·06
„ 4th „ „	3·220	2·99	1·52
„ 5th „ „	·910	·89	·31
„ 6th „ „	·118	·22	·27
Total chlorine . .	35·148	35·33	42·74

By the above table it can be perceived that in the English sample there was only ·251, and in the Swiss ·43, and in the laboratory sample ·44 per cent. of chlorine yet to be accounted for, and on washing the samples twice with distilled water, each time with 200 c.c., and again estimating the chlorine in the filtrates, they were found to contain as follows:

	English Bleach. Per cent.	Swiss Bleach. Per cent.	Laboratory Bleach. Per cent.
Chlorine in 1st 200 c.c.	·198	·270	·19
„ 2nd „	·007	·051	·12

Though the samples were now washed with successive 100 c.c. of water up to 1500 c.c., only ·0392 per cent. of chlorine could be estimated in the English bleach, ·09 per cent. in the Swiss, and ·112 per cent. in the laboratory bleach. After this the filtrates were not examined; but an accurate account was kept of the quantity of water used, and when each sample had been washed with 1800 c.c. the reaction with the iodine and starch paper was very uncertain; but on adding iodine and starch solution to the filtrate, together with acetic acid, an immediate reaction occurred, which was the case with these particular samples until 3000 c.c. of water had been used to wash each 10 grammes of bleaching powder; after that quantity of water had been used, chlorine could no longer be detected, either with the starch paper or starch solution and acetic acid, though each sample was kept covered with 100 c.c. of water for many hours, by closing the bottom of the funnels. This part of the investigation was repeated many times, and the quantity of water used to extract the chlorine varied widely with different samples, as well as the rate at which it was extracted (that depending greatly on various circumstances: 1st, On the percentage of chlorine in the sample; 2nd, On the temperature of the water, and degree of fineness of the sample; 3rd, On the speed at which it is washed by the pump). On various occasions the quantity of water required to extract the chlorine from 10 grammes amounted to as much as 5000 c.c. This probably arose from not having the cone of parchment paper large enough, thereby allowing a small quantity of suspended matter to be carried through the Swedish filter paper; or it not improbably arose from the difficulty of preventing the first portions of the strong hypochlorite solution from coating the inside of the tube of the funnels, and thereby contaminating the latter filtrates. But even when more than 5000 c.c. of water had been employed to wash 10 grammes, the filtrate, which had long ceased to give a reaction with starch paper, still continued to do so very decidedly with the iodine and starch solution together with an acid; but on the addition of an extra cone of Swedish paper to the one already in the funnel, the reaction no longer appeared. It was considered advisable to estimate the remaining chlorine in the residue of various samples when they no longer gave a reaction with the starch paper, but continued to do so with the acid and starch solution. This was done by washing the residue into a beaker and dissolving it by the addition of as small a quantity of acetic acid as possible, and then diluting, after which the chlorine was estimated by the arsenious acid process as rapidly as possible.

Though numerous residues were examined at this stage of the washing, the highest percentage of chlorine found was only ·007 per cent., and the lowest ·0032 per cent.

The percentage of residue in the various samples was determined in two stages: (1st) When the samples had been washed till they no longer gave a decided reaction with the starch paper; (2nd) After complete washing.

The percentage of residue in the partially washed samples was found to

vary largely with each sample, as is to be expected; indeed, so largely did they diverge from one another, that no definite percentage could be given as likely to exist in a partially washed sample of bleaching powder. The samples which were examined in this investigation ranged between 22 and 30 per cent. The percentage of residue in the completely washed samples did not show such a large variation. In the particular samples, the percentage of chlorine in which is given above, there was found in the English sample 8·1 per cent. residue, in the Swiss sample 7·9 per cent. And an examination of various samples of bleaching powder of different strengths showed that the percentage only varied between 7 per cent. and 9 per cent.

The remaining part of this investigation presented many difficulties. The residue, which had failed to give a reaction with the iodine and starch solution, together with acetic acid, when dried, certainly did evolve, on the addition of a few drops of hydrochloric or sulphuric acid, a most minute quantity of a body which slightly acted on wet iodine and starch paper; but so small was the quantity of this body which could be obtained, though several pounds of residue were experimented with, that no correct idea of its nature could be formed; but the results of the numerous experiments made with it went to prove that it is not a basic chlorate, as stated by Persoz, but simply a trace of a soluble hypochlorite which escaped being removed from the residue by washing.

Many attempts were made to estimate, in the completely washed residue, this trace of a bleaching agent, in a manner similar to that adopted for its estimation in the partially washed residue, but without success.

As to Persoz's statement that, when the residue is completely deprived of its bleaching power, and then spread over woven fabrics in such a manner as to find its way into their interstices, if the fabrics be then submitted to a bath of hydrochloric acid, so energetic is the gas evolved from this supposed basic chlorate, that the fabrics are burnt into holes in many places;—this statement, so far as these experiments go, is certainly without foundation, though the residue was tortured in every conceivable manner in the endeavour to detect in it any body capable of injuring textile fabrics. Among the experiments made with it, the following are a few:—

1st. A certain weight of the residue was mixed with just sufficient water to allow it to penetrate through the fabric being experimented with; this mixture was then pasted on one end of a piece of fine unbleached cotton. The same weight of a mixture of lime and carbonate of lime as of the residue was mixed with the same quantity of water, and then pasted on the other end of the piece of cotton. The cotton was now set aside until the residue and lime mixture had dried on it, after which, by means of a fine dropping tube, the same quantity of a normal hydrochloric acid solution was poured over the residue and lime mixture, and when all effervescence had ceased, a few drops more acid were added, and the piece of cotton allowed to rest for some time, after which it was washed; and on examination the result was found to be the same with the lime as with the residue—both ends of the cotton were slightly yellow, but in no way bleached or damaged.

This experiment was repeated many times in various ways, and with a variety of fabrics, such as unbleached linen, bleached linen, calico, and cotton printed with fugitive colours; but though the unbleached linen and cotton were boiled in a solution of the residue, and then passed through an acid bath, no more effect could be perceived than when a piece of the same goods was boiled in a solution of the same quantity of the mixture of lime and carbonate of lime, and then passed through the acid bath. In case it might be considered that boiling had a neutralising effect on any basic chlorate existing in the residue, various pieces of different fabrics were allowed to steep in a solution of the residue for over a week, and then placed for several hours in an acid bath, without being in the least degree injured. When the fugitive colour on the printed calico was not altered by lime, neither was it affected by the bleaching powder residue. In order to correctly investigate the remaining question, queries were addressed to several of the best known proprietors of Irish linen bleach-greens, as to the exact method adopted by them for the manufacture of the hypochlorite of lime solution, and also the quantity of water used to

wash a certain weight of powder. From the answers received, it was ascertained that no general rule was followed, everyone doing what he considered best for his purpose; but it was considered probable that the damage to fabrics noticed by Persoz arose from minute particles of unwashed, or imperfectly washed, bleaching powder finding their way into the interstices of the fabrics, which afterwards had been so imperfectly washed that when they were passed through the acid bath an energetic bleaching agent was evolved, and so the fabric was destroyed. To determine whether this was likely to be the case, bleaching powder was dissolved, and the residue washed in the manner adopted at one of the largest greens in Ireland; and in the residue thus prepared, pieces of linen and cotton were steeped for twenty-four hours, after which they were found to be still sound, but decidedly altered in colour, and after being passed through an acid bath, both samples were of that shade of colour known in the trade as a 'low cream.'

On washing bleaching powder according to the manner adopted at several greens, and then estimating the chlorine remaining in the residues, it was found to vary from ·2 per cent. to ·7 per cent.; and from these figures and the above experiments there can be no doubt but that the damage, if any, arises, not from a basic chlorate, but from a number of infinitesimal particles of the undissolved bleaching powder becoming lodged in the interstices of the fabrics; and, of course, those parts where they were lodged would require a great deal more washing than the remaining portions of the fabric; and if, either by carelessness or any other cause, the goods happened to be imperfectly washed, then, when soured, they would not unlikely be damaged in the parts containing the undissolved particles by the evolved gas, while the remaining portions would be unaltered.

In conclusion, I must take this opportunity of thanking Professor Lunge, under whose supervision these experiments were carried out, for the many valuable suggestions which he was kind enough from time to time to make.

Section C.—GEOLOGY.

President of the Section—H. Clifton Sorby, LL.D., F.R.S., F.G.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

In selecting a subject for an address to be given in accordance with the custom of my predecessors, I was anxious that it should be, in some way or other, connected with the locality in which we have met. If I had been adequately acquainted with the district, I should have thought it incumbent on me to give such an outline of the general geology of the surrounding country as would have been useful to those attending this meeting. I am, however, practically a stranger to South Wales, and must therefore leave that task to others. On reflecting on the various subjects to which I might have called your attention, it appeared to me that I could select one which would be eminently appropriate in a town and district where iron and copper are smelted on so large a scale, and, as I think, also equally appropriate from a geological point of view. This subject is the comparative structure of artificial slags and erupted rocks. In making this choice I was also influenced by the fact that in my two anniversary addresses as President of the Geological Society I have recently treated on the structure and origin of modern and ancient stratified rocks, and I felt that, if in the present address I were to treat on certain peculiarities in the structure of igneous rocks, I should have described the leading conclusions to which I have been led by studying the microscopical structure of nearly all classes of rocks. It would, however, be impossible in the time now at disposal to treat on all the various branches of the subject. Much might be said on both the purely chemical and purely mineralogical aspects of the question; but though these must not be ignored, I propose to draw your attention mainly to another special and remarkable class of facts, which, so far as I am aware, have attracted little or no attention, and yet, as I think, would be very instructive if we could fully understand their meaning. Here, however, as in so many cases, the observed facts are clear enough, but their full significance somewhat obscure, owing to the want of adequate experimental data or sufficient knowledge of general physical laws.

A considerable amount of attention has already been paid to the mineral constitution of slags, and to such peculiarities of structure as can be learned independently of thin microscopical sections. A very complete and instructive work, specially devoted to the subject, was published by Von Leonhard about twenty-two years ago, just at the time when the microscope was first efficiently applied to the study of rocks. Since then Vogelsang and others have described the microscopical structure of some slags in connexion with their studies of obsidian and other allied volcanic rocks. At the date of the publication of Von Leonhard's work the questions in discussion differed materially from those which should now claim attention. There was still more or less dispute respecting the nature and origin of certain rocks which have now been proved to be truly volcanic by most unequivocal evidence; and I am not at all surprised at this, since, as I shall show, there is such a very great difference in their characteristic structure and that of the artificial products of igneous fusion, that, but for the small portions of glass inclosed in the constituent crystals, described by me many years ago under the name of

'glass-cavities,' there would often be no positive proof of their igneous origin. There was also considerable doubt as to the manner in which certain minerals in volcanic rocks had been generated. The observed facts were sufficient to prove conclusively that some had been formed by sublimation, others by igneous fusion, and others deposited from more or less highly heated water; but it was difficult or impossible to decide whether in particular cases certain minerals had been formed exclusively by one or other process, or sometimes by one and sometimes by the other, or by the combined action of water and a very high temperature. I must confess that, even now that so much may be learned by studying with high magnifying powers the internal structure of crystals, I should hesitate very much in deciding what were the exact conditions under which certain minerals have been formed. This hesitation is probably as much due to inadequate examination and to the want of a complete study of typical specimens, both in the field and by means of the microscope, as to the unavoidable difficulties of the subject. Such doubt, however, applies more to the origin of minerals occurring in cavities than to those constituting a part of true rock-masses, to which latter I shall almost exclusively refer on the present occasion. In the formation of these it appears to me that sublimation has occurred to a very limited extent. In many cases true igneous fusion has played such a leading part that the rocks may be fairly called *igneous*, but in other cases, water, in some form or other, has, I think, had so much influence that we should hesitate to call them *igneous*, and the term *erupted* would be open to far less objection, since it would adequately express the manner of their occurrence, and not commit us to anything open to serious doubt.

In studying erupted rocks of different characters, we see that at one extreme they are as truly igneous as any furnace-product, and, at the other extreme, hardly, if at all, distinguishable from certain deposits met with in mineral veins, which furnish abundant evidence of the preponderating, if not exclusive, influence of water, and have very little or nothing in common with products certainly known to have been formed by the action of heat, and of heat alone. Between these extremes there is every connecting link, and in certain cases it is almost, if not quite impossible to say whether the characteristic structure is due more to the action of heat than of water. The great question is, whether the presence of a small quantity of water in the liquid or gaseous state is the true cause of very well-marked differences in structure; or whether greater pressure, and the necessarily slower rate of cooling, were not the more active causes, and the presence of water in one state or another was merely the result of the same cause. This is a question which ought to be solved by experiment; but I fear it would be almost impossible to perform the necessary operations in a satisfactory manner.

What I now propose to do is to describe a particular class of facts which have lately attracted my attention, and to show that the crystalline minerals in products known to have been formed by the action of heat alone, have a certain very well-marked and characteristic structure, which is gradually modified as we pass through modern and more ancient volcanic to plutonic rocks, in such a manner as to show at once that they are intimately related, and yet differ in such characteristic particulars that I think other agencies than mere heat must have had great influence in producing the final result.

In dealing with this subject, I propose, in the first place, to describe the characteristic structure of products formed artificially under perfectly well-known conditions, and then to pass gradually to that of rocks whose origin must be inferred, and cannot be said to have been completely proved.

Crystalline Blowpipe Beads.

Some years ago I devoted a considerable amount of time to the preparation and study of crystalline blowpipe beads, my aim being to discover simple and satisfactory means for identifying small quantities of different earths and metallic oxides, when mixed with others; and I never supposed that such small objects would throw any light on the structure and origin of vast masses of natural rock. The manner in which I prepared them was as follows: A small bead of borax was

so saturated with the substance under examination at a high temperature, that it became opaque either on cooling or when slowly re-heated. It was again fused so as to be quite transparent, and then very slowly cooled over the flame. If properly managed, the excess of material held in solution at a high temperature slowly crystallised out, the form and character of the crystals depending on the nature of the substance and on the presence of other substances added to the bead as test reagents. By this means I proved that in a few exceptional cases small simple solid crystals are formed. More frequently they are compound, or occur as minute needles, but the most characteristic peculiarity is the development of complex skeleton crystals of extreme beauty, built up of minute attached prisms, so as to give rise to what would be a well-developed crystal with definite external planes, if the interspaces were all filled up. In many cases the fibres of these skeletons are parallel to three different axes perpendicular to one another, and it might be supposed that the entire skeleton was due to the growth of small needle-shaped crystals all uniformly elongated in the line of one crystalline axis, so that the resulting mass would be optically and crystographically complex; but in some cases the different systems of fibres or needles are inclined obliquely, and then the optical characters enable us to prove that the separate prisms are not similar to one another, but developed along different crystalline planes, so as to build up one definite crystal, mechanically complex, but optically and crystallographically simple, or merely twinned. In a few special cases there is a well-pronounced departure from this rule, and truly compound groups of prisms are formed. In the centre there is a definite simple prism; but instead of this growing continuously in the same manner, so as to produce a larger prism, its ends, as it were, break up into several smaller prisms, slightly inclined to the axis of the first; and these secondary prisms, in like manner, break up into still smaller, so as ultimately to give rise to a curious complex brush-like growth, showing in all positions a sort of fan-shaped structure, mechanically, optically, and crystallographically complex.

I have done my best to describe these various kinds of crystals seen in blowpipe beads as clearly as can be done without occupying too much time, but feel that it is impossible to make the subject as simple as it really is without numerous illustrations. However, for the purpose now in view, it will, I trust, suffice to have established the fact that we may divide the crystals in blowpipe beads into the following groups, which on the whole are sufficiently distinct, though they necessarily pass one into the other.

1. Simple crystals.
2. Minute detached needles.
3. Fan-shaped compound groups.
4. Feathery skeleton crystals.

It must not be supposed that crystals of one or other of these groups occur promiscuously and without some definite relation to the special conditions of the case. Very much depends upon their chemical composition. Some substances yield almost exclusively those of one group, and other substances those of another, whilst in some cases a difference in the rate of cooling and other circumstances give rise to variations within certain limits; and, if it were possible to still further vary some of the conditions, these limits would probably be increased. Thus, for example, the earliest deposition of crystalline matter from the glassy solvent is sometimes in the form of simple solid prisms or needles, but later on in the process it is in the form of compound feathery tufts; and if it were possible to cool the beads much more slowly whilst they are very hot, I am inclined to believe that some substances might be found that in the early stage of the process would yield larger and more solid crystals than those commonly met with. This supposition, at all events, agrees with what takes place when such salts as potassium chloride are crystallised from solution in water. Some of my blowpipe beads prove most conclusively that several perfectly distinct crystalline substances may be contemporaneously deposited from a highly heated vitreous solvent, which is an important fact in connection with the structure of igneous rocks, since some authors have asserted that more than one mineral species cannot be formed by the slow cooling of a truly melted rock. The great advantage of studying artificial

blowpipe beads is that we can so easily obtain a variety of results under conditions which are perfectly well known, and more or less completely under control.

Artificial Slags.

I now proceed to consider the structure of slags, and feel tempted to enter into the consideration of the various minerals found in them which are more or less perfectly identical with those characteristic of erupted rocks; but some of the most interesting, like the felspars, occur in a well-marked form only in special cases, where iron ores are smelted with fluxes seldom, if ever, employed in our own country, so that my acquaintance with them is extremely small. My attention has been mainly directed to the more common products of our blast-furnaces. On examining these, after having become perfectly familiar with the structure of blowpipe beads, I could see at once that they are very analogous, if not identical in their structure. In both we have a glassy solvent, from which crystals have been deposited; only in one case this solvent was red hot, melted borax, and in the other glassy, melted stone. Thus, for example, some compounds, like what I believe is Humboldtilite, crystallise out in well-marked solid crystals, like those seen occasionally in blowpipe beads, whereas others crystallise out in complex feathery skeletons, just like those so common in and characteristic of the beads. In both we also often see small detached needles, scattered about in the glassy base. These skeleton crystals and minute needles have been described by various writers, under the names, *crystallites*, *belonites*, and *trichites*. Though we have not the great variety of different forms met with in the beads, and cannot so readily vary the conditions under which they are produced, yet we can, at all events, see clearly that their structural character depends both on their chemical constitution and on the physical conditions under which they have crystallised. None of my microscopical preparations of English slags appear to contain any species of felspar, but several contain what I believe is some variety of augite, both in the form of more or less solid prisms, and of feathery skeletons of great beauty and of much interest in connection with the next class of products to which I shall call your attention, viz., rocks artificially melted and slowly cooled.

Rocks artificially melted.

I have had the opportunity of preparing excellent thin microscopical sections of some of the results of the classic experiments of Sir James Hall. I have also carefully studied the product obtained by fusing and slowly cooling much larger masses of the basalt of Rowley, and have compared its structure with that of the original rock. Both are entirely crystalline, and, as far as I can ascertain, both are mainly composed of the same minerals. Those to which I would especially call attention are a triclinic felspar and the augite. The general character of the crystals is, however, strikingly different. In the artificial product a considerable part of the augite occurs as flat, feathery plates, like those in furnace slags, which are quite absent from the natural rock, and only part occurs as simple solid crystals, analogous to those in the rock, but much smaller and less developed. The felspar is chiefly in the form of elongated, flat, twinned prisms, which, like the prisms in some blowpipe beads, commence in a more simple form and end in complex fan-shaped brushes, whereas in the natural rock they are larger than in the artificial, and exclusively of simple character. On the whole, then, though the artificially melted and slowly cooled basalt is entirely crystalline, and has a mineral composition closely like that of the natural rock, its mechanical structure is very different, being identical with that of blowpipe beads and slags.

Volcanic Rocks.

Passing now to true natural igneous rocks, we find some, like obsidian, which closely correspond with blowpipe beads, slags, and artificially melted rocks, in having a glassy base, through which small crystalline needles are scattered; but the more completely crystalline volcanic rocks have, on the whole, a structure

very characteristically unlike that of the artificial products. I have most carefully examined all my sections of modern and ancient volcanic rocks, but cannot find any in which the augite or magnetite is crystallised in feathery skeletons. In the case of only one single natural rock, from a dyke near Beaumaris, have I found the triclinic felspar arranged in just the same fan-shaped, brush-like groups as those in similar rocks artificially melted and slowly cooled. The large solid crystals in specimens from other localities sometimes show that towards the end of their growth small flat prisms were developed on their surface, analogous to those first deposited in the case of the artificial product. In slags composed almost exclusively of what I believe is Humboldtilite, the crystals are indeed uniformly as simple and solid as those in natural rocks, but the examination of different blowpipe beads shows that no fair comparison can be made between altogether different substances. We must compare together the minerals common to the natural and the artificial products, and we then see that, on the whole, the two classes are only just distinctly connected by certain exceptional crystals and by structural characters which, as it were, overlap enough to show that there is a passage from one type to the other. In the artificial products are a few small, solid crystals of both augite and a triclinic felspar, which closely correspond to the exceptionally small crystals in the natural rocks; but the development of the great mass of the crystals is in a different direction in the two cases. In the artificial products it is in the direction of complex skeletons, which are not seen in the natural rock; but in the natural rock it is in the direction of large simple solid crystals, which are not met with in the artificial products. There is a far closer analogy in the case of partially vitreous rocks, which, independent of the true glassy base common to them and the artificial products, often contain analogous crystalline needles. Even then, however, we see that in the artificial product the crystals tend to develop into complex skeletons, but in the natural rocks into simple solid crystals.

It must not be supposed that these facts in any way lead me to think that thoroughly crystalline modern and ancient volcanic rocks were never truly fused. The simple, large, and characteristic crystals of such minerals as augite, felspar, leucite, and olivine, often contain so many thoroughly well-marked glass enclosures, as to prove most conclusively that when the crystals were formed they were surrounded by, and deposited from, a melted glassy base, which was caught up by them whilst it was still melted. This included glass has often remained unchanged, even when the main mass became completely crystalline, or has been greatly altered by the subsequent action of water. I contend that these glass enclosures prove that many of our British erupted rocks were of as truly igneous origin as any lava flowing from a modern volcano. The difference between the structure of such natural rocks and that of artificial slags must not, in my opinion, be attributed to the absence of true igneous fusion, but to some difference in the surrounding conditions, which was sufficient to greatly modify the final result, when the fused mass became crystalline on cooling. The observed facts are clear enough, and several plausible explanations might easily be suggested, but I do not feel at all convinced that any single one would be correct. That which first suggests itself is a much slower cooling of the natural rocks than is possible in the case of the artificial products; and I must confess that this explanation seems so plausible that I should not hesitate to adopt it, if certain facts could be accounted for in a satisfactory manner. Nothing could be more simple than to suppose that skeleton crystals are formed when deposition takes place in a hurried manner, and they so overgrow the supply that they develop themselves along certain lines of growth before there has been time to solidly build up what has been roughly sketched in outline. I cannot but think that this must be a true and, to some extent, active cause, even if it be inadequate to explain all the facts. What makes me hesitate to adopt it by itself is the structure of some doleritic rocks when in close contact with the strata amongst which they have been erupted. In all my specimens the effects of much more rapid cooling are perfectly well marked. The base of the rock when in close contact is sometimes so extremely fine-grained that it is scarcely crystallised, and is certainly far less crystalline and finer grained than the artificial products to which I have called attention, and yet

there is no passage towards those structures which are most characteristic of slags, or at least, no such passage as I should have expected if these structures depended exclusively on more rapid cooling.

We might well ascribe something to the effect of mass, but one of my specimens of basalt melted and slowly cooled in a small crucible is quite as crystalline as another specimen taken from a far larger mass, though I must confess that what difference there is in this latter is in the direction of the structure characteristic of natural rocks. The presence or absence of water appears to me a very probable explanation of some differences. When there is evidence of its presence in a liquid state during the consolidation of the rock we can scarcely hesitate to conclude that it must have had some active influence; but in the case of true volcanic rocks the presence of liquid water is scarcely probable. That much water is present in some form or other, is clearly proved by the great amount of steam given off from erupted lavas. I can scarcely believe that it exists in a liquid state, except at great depths, but it may possibly be present in a combined form or as a dissolved vapour under much less pressure, and the question is whether this water may not have considerable influence on the growth of crystals formed prior to eruption, before it was given off as steam. I do not know one single fact which can be looked upon as fairly opposed to this supposition, and it is even to some extent supported by experiment. M. Daubrée informs me that the crystals of augite formed by him at a high temperature by the action of water have the solid character of those in volcanic rocks, and not the skeleton structure of those met with in slags. The conditions under which they were formed were, however, not sufficiently like those probably present during the formation of erupted lavas to justify our looking upon the explanation I have suggested as anything more than sufficiently plausible, in the absence of more complete experimental proofs.

Granitic Rocks.

I now proceed to consider rocks of another extreme type, which for distinction we may call the granitic. On the whole, they have little or nothing in common with slags, or with artificial products similar to slags, being composed exclusively of solid crystals, analogous in character only to slag-crystals of very different mineral nature. As an illustration, I would refer to the structure of the products formed by fusing and slowly cooling upwards of a ton of the syenite of Grooby, near Leicester. Different parts of the resulting mass differ very materially, but still there is an intimate relation between them, and a gradual passage from one to the other. The most characteristic feature of those parts which are completely crystalline is the presence of beautiful feathery skeleton-crystals of magnetite, and of long flat prisms of a triclinic felspar, ending in complex, fan-shaped brushes. There are no solid crystals of felspar, hornblende, and quartz, of which the natural rock is mainly composed, to the entire exclusion of any resembling those in the melted rock. As looked upon from the point of view taken in this address, the natural and artificial products have no structural character in common, so that I think we must look for other conditions than pure igneous fusion to explain the greatly modified results. We have not to look far for evidence of a well-marked difference in surrounding circumstances. The quartz in the natural rock contains vast numbers of fluid-cavities, thus proving that water was present, either in the liquid state or as a vapour so highly compressed that it afterwards condensed into an almost equal bulk of liquid. In some specimens of granite there is indeed clear proof that the water was present as a liquid, supersaturated with alkaline chlorides, like that inclosed in the cavities of some minerals met with in blocks ejected from Vesuvius, which also have to some extent what may be called a granitic structure. In the case of one very exceptional and interesting granite, there is apparently good proof that the felspar crystallised out at a temperature above the critical point of water—that is to say, at a temperature higher than that at which water can exist as a liquid under any pressure—and it caught up highly compressed steam, comparatively, if not entirely, free from soluble salts; whereas the quartz crystallised when the temperature was so far lowered as to be below the critical

point, and the water had passed into a liquid, supersaturated with alkaline chlorides, which have crystallised out as small cubes in the fluid-cavities, just as in the case of minerals in some of the blocks ejected from Vesuvius.

Confining our attention, then, to extreme cases, we thus see that rocks of the granitic type differ in a most characteristic manner from the products of artificial igneous fusion, both in the structure of the crystals and in containing liquid water, inclosed at the time of their formation. The question then arises, whether these differences were due to the presence of the liquid water, or whether its presence and the characteristic structure were not both the effects of the great pressure of superincumbent rocks. I do not see how this can be decided in a perfectly satisfactory manner, but must confess that I am inclined to believe that, whilst great pressure was necessarily the reason why the water did not escape as vapour, the presence of liquid water during final consolidation must have had a very considerable influence in modifying the structure of the rock, and had a great share in developing what we may call the granitic type.

It would be very instructive to follow out the gradual passage from one extreme type to another far more completely than is possible on the present occasion. The most interesting examples of rocks intermediate between the granitic and volcanic types that I have been able to examine in adequate detail, are the various Cornish elvans and other quartz felsites, which furnish all but a complete passage from pitchstone to granite. Some specimens prove that quartz may crystallise out from and inclose a perfectly glassy base, without a trace of liquid water; and at the same time other specimens prove equally well that, as we approach the granitic type, the quartz was not deposited from a glassy solvent, but inclosed more or less water. In the few intermediate cases there appears to be evidence of the conjoint presence of uncombined water and melted stony matter. On the whole, if we take into consideration only the external form of the larger crystals, rocks of the granitic type are very much as though the crystals met with in truly volcanic rocks had been strained out from the glassy or fine-grained base, and the intermediate spaces filled with quartz. The internal structure of the crystals is, however, very different, the cavities in one class containing glass, and in the other water. This most essential and characteristic difference proves that rocks of the true granitic type cannot have been formed simply by the more complete crystallisation of the general base of the rock. If the crystals in granite were analogous to those developed in volcanic rocks, and the only essential difference was that the residue crystallised out more slowly and completely, so as to give rise to a more coarsely crystallised base, the crystals first formed ought not, as I think, to differ so essentially as that in one case they should inclose only glass, and in the other only water. Taking all into consideration, we can therefore scarcely suppose that the crystals in granitic rocks were deposited from a truly-melted, dry, glassy solvent, like those in volcanic rocks or in slags.

General Results.

I have, I trust, now said enough to show that the objects here described may be conveniently separated into three well-marked groups, viz., artificial slags, volcanic rocks, and granitic rocks. My own specimens all show perfectly well-marked and characteristic structures, though they are connected in some cases by intermediate varieties. Possibly such connecting links might be more pronounced in other specimens that have not come under my notice. I must, however, base my conclusions on what I have been able to study in an adequate manner, by examining my own preparations, and leave it for others to correct any errors into which I may have been led from lack of more numerous specimens. In any case the facts seem abundantly sufficient to prove that there must be some active cause for such a common, if not general, difference in the structural character of these three different types. The supposition is so simple and attractive, that I feel very much tempted to suggest that this difference is due to the presence or absence of water as a gas or as a liquid. In the case of slags it is *not* present in *any* form. Considering how large an amount of steam is given off from erupted lavas, and that, as a rule, no

fluid-cavities occur in the constituent minerals, it appears to me very plausible to suppose that those structures which are specially characteristic of volcanic rocks are in great measure, if not entirely, due to the presence of *associated* or *dissolved vapour*. The fluid-cavities prove that water was sometimes, if not always, present as a *liquid* during the consolidation of granitic rocks; and we can scarcely hesitate to conclude that it must have had very considerable influence on the rock during consolidation. Still, though these three extreme types appear to be thus characterised by the absence of water, or by its presence in a state of vapour or liquid, I think we are scarcely in a position to say that this difference in the conditions is more than a plausible explanation of the differences in their structure. At the same time, I do not know any facts that are opposed to this conclusion, and we should, perhaps, not greatly err in thus correlating the structures, even though the water was not the essential and active cause of the differences.

Confining our attention to the more important crystalline constituents which are common to the different types, we may say that the chief structural characters of the crystals are as follows:—

a. Skeleton crystals.
b. Fan-shaped groups.
c. Glass-cavities.
d. Simple crystals.
e. Fluid-cavities.

These different structural characters are found combined in different ways in the different natural and artificial products; and for simplicity I will refer to them by means of the affixed letters.

The type of the artificial products of fusion may generally be expressed by $a+b$ or $b+c$, that is to say, it is characterised by skeleton crystals and fan-shaped groups, or by fan-shaped groups and glass-cavities. In like manner the volcanic type may be expressed occasionally by $b+c$, but generally by $c+d$; and the granitic by $d+e$. These relations will be more apparent if given in the form of a table, as follows:—

Slag type . .	$\left\{ \begin{array}{l} a+b \\ b+c \end{array} \right.$
Volcanic type . .	$\left\{ \begin{array}{l} b+c \\ c+d \end{array} \right.$
Granitic type	$d+e$.

Hence it will be seen that there is a gradual passage from one type to the other by the disappearance of one character and the appearance of another, certain characters the meanwhile remaining common, so that there is no sudden break, but an overlapping of structural characteristics. It is, I think, satisfactory to find that, when erupted rocks are examined from such a new and independent point of view, the general conclusions to which I had been led are so completely in accord with those arrived at by other methods of study.

Conclusion.

And now I feel that it is time to conclude. I have necessarily been compelled to give only a general account of the subject, and perhaps, for want of adequate description, many facts may appear more complex than they really are. Some are, indeed, of anything but simple character, and their full explanation is, perhaps, beyond our present power. The greater part are, however, much more simple and easy to observe than to describe; and, even if I have failed to make everything as plain as I could wish, I hope I have succeeded in making the principal point sufficiently clear to show that the structure of slags and of analogous artificial products throws much light on the structure and origin of the various groups of erupted rocks. I feel that very much still remains to be learned, and, as I think, could be learned, by the further extension of this method of inquiry. What strikes me most is the great necessity for the more complete application of experimental methods of research; but to carry out the experiments necessary to clear up

the essential difficulties of the subject would, I fear, be a most difficult undertaking. In the meantime all that we can do is to compare the structure of known artificial products with that of natural rocks, and to draw the best conclusions we can from the facts, as viewed in the light of our present knowledge of chemistry and physics. My own impression is that there is still much to be learned respecting the exact conditions under which some of our commonest rocks were formed.

The following Reports and Papers were read:—

1. *Sixth Report on the Circulation of the Underground Waters in the Permian, New Red Sandstone, and Jurassic Formations of England, and the Quantity and Character of the Water supplied to towns and districts from those formations.*—See Reports, p. 87.

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2. *Notes on the Submarine Geology of the English Channel off the Coast of South Devon.*[1] *By* Arthur Roope Hunt, *M.A., F.G.S.*

The author described and exhibited hand specimens of the large detached blocks of serpentine, gabbro, conglomeratic grit, granite, hornblendic granite, and other granitic or gneissic rocks that are occasionally trawled by the Brixham fishermen in the English Channel, off the southern headlands of Devonshire. From the fact that the nearest known rocks on the north-west are the gneisses of the Eddystone, and those on the north and north-east are the micaceous slates of the Start and Bolt district, it would seem probable that the detached blocks indicate similar rocks *in sitû,* and that they are not erratics.

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3. *On the Action of Carbonic Acid on Limestone.* *By* Professor W. Boyd Dawkins, *M.A., F.R.S.*

Caves in limestone are to be looked upon as subterranean watercourses, which are produced partly by the dissolving action of the carbonic acid in the rainwater, and partly by the mechanical action of the streams flowing through the caves. The insoluble carbonate of lime in the rock is changed into the soluble bi-carbonate, and is carried away in solution. The additional atom of carbonic acid, however, is in a condition of unstable chemical combination, and if it be removed, either by evaporation or by the action of the free current of air, the insoluble carbonate of lime is at once deposited. Hence it is that some caverns have their walls covered with a drapery of stalactite, and the little straw-like pendants from the roof formed round the edges of each drop gradually become developed into columns of various sizes. The stalagmitic pedestals also rise from the floor where a line of drops falls from the roof, and ultimately unite with the column let down from above. On the surface, too, of the pools an ice-like sheet of stalagmite gradually shoots across from the sides, and sometimes, where the water is still, covers the whole surface. Admirable illustrations of all these processes are to be seen in the caves of Pembrokeshire, and especially in the Fairy Cave on Caldy Island.

The rate of the accumulation of carbonate of lime, depending primarily upon the access of water and the free access of air, both being variable, varies in different places. Sometimes it is very swift, as for example in the Ingleborough Cave; where a series of observations by Professor Phillips, Mr. Farrar, and myself, extending over the years from 1845 to 1873, give the annual rate at ·2946 inch. It is obvious, therefore, that all speculation as to the antiquity of deposits, in cases which are based on the view that the accumulation is very slow, are without value.

The narrow mountain-limestone ravines and passes are to be viewed, in the main, as caverns formed in the manner above stated, which have lost their roofs by the various sub-aëreal agents which are ever at work attacking the surface

[1] See *Transactions Devonshire Association* for 1880.

of the limestone. If any of these ravines be examined, it will be seen that the tributary caves open on their sides, and in some cases the ravine itself is abruptly terminated by a cavern.

4. *On the site of a Palæolithic Implement Manufactory, at Crayford, Kent. By* F. C. J. Spurrell, *F.G.S.*

The remains exhibited were found by Mr. Spurrell in March last in the chalk pit half a mile north-east of Crayford Church. The flakes and bones associated with them were found under a deposit of brick earth, lying against an ancient chalk cliff of the river Thames, about forty feet below the present surface of the ground.

They consist mainly of waste flakes, flakes used at the broad end, an unfinished hâche, cores, and stones employed as hammers. From the fact that the edges are sharp, that the chips belonging to individual blocks of flint lie together and can be joined to one another, and that they lie in a layer together with the finest chippings scarcely mixed with the sand, it is clear that the work was carried on where the *débris* lay.

The blocks of flint were derived from the weathering of the chalk cliff, and were not mined; they were of a very inferior quality; and probably it is to this piece of luck, and the consequent excess of waste material, that the find was not overlooked.

Portions of the bones of mammoth, tichorhine, rhinoceros, horse, &c., lay among the flakes and immediately upon them, and present the appearance of having been broken by man—perhaps for food.

5. *On the Hiatus said to have been found in the rocks of West Cork. By* G. H. Kinahan, *M.R.I.A., Pres. Royal Geological Society, Ireland.*

The author gave a table of the classifications of the Cork rocks—

Griffith.	Jukes.	Hull.
Carboniferous slate.	Carboniferous slate.	Carboniferous slate. Coomhoola grits.
Yellow sandstone.	Upper Old Red sandstone.	Kiltorcan beds.
Old Red sandstone.	Lower Old Red sandstone.	Glengariff beds (Silurian).
Silurian.	Glengariff grits.	

from which it was seen that Griffiths' and Jukes' classifications were essentially similar, while Professor Hull's was materially different; the difference being greater than at first appears from the nomenclature employed.

He pointed out that the supposed hiatus rested on the statements of Professor Hull, all of which were reviewed. The *first* series of statements was that the *hiatus* in the neighbourhood of Kenmare and Glengariff bays was found by Messrs. O'Kelly and McHenry; but the first of these geologists contradicts this, while the second declined to give an opinion. The author then pointed out that the Glengariff section, in which this 'great hiatus' is said to exist, was Jukes's type section, to which he brought Professor Ramsay and Salter on their visit to the country, and by which he taught his assistants, Messrs. Foot, O'Kelly, and the author, the classification of the West Cork rocks. The *second* series of statements was concerning well-known unconformabilities; but as these are outside the limits of the area occupied by the West Cork rocks, they prove nothing in connection with them. The *third* set of statements was that the plotting of the folded and flexuous strata proved unconformabilities. These the author showed to be only conventional lines, which are explained by the published sections and writings of Jukes and his colleagues. The *fourth* statements were abrupt changes from one of Professor Hull's groups to the others. This the author showed could not be correct, as the Carboniferous slate graduated so imperceptibly into the Yellow Sandstone, and the latter into the Old Red Sandstone, that the respective boundaries are most arbitrary, and depend only on the colours of certain beds.

In conclusion the author pointed out the difficulties in understanding the principles of Professor Hull's classification. He also showed that Professor Hull's use of Jukes' and Griffiths' names and terms, in a sense different from that in which they were understood by those authors, had introduced confusion.

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6. *Note on the Range of the Lower Tertiaries of East Suffolk. By* W. H. Dalton, *F.G.S., of the Geological Survey of England.*

The Crags and Drifts of East Suffolk prevent more than an approximate delineation of the outcrop of the Chalk from beneath the Lower Tertiary beds.

The London Clay disappears from the surface a little west of Orford; but the deep boring at Sir E. Lacon's brewery in Yarmouth, made in 1840, passed through 170 feet of estuarine deposits, and then no less than 305 feet of London Clay and 51 of Reading Beds before reaching the Chalk. There could therefore be hardly a doubt of the continuity of the Eocene beds between Orford and Yarmouth, although their boundary-line might be for some part of its length outside of the present coast; indeed, in published maps, most of the interval is coloured as Chalk.

The inhabitants of Suffolk are, however, awaking to the disadvantages of a water-supply derived from ponds and sewage-tainted sands, and consequently Artesian wells, carried down into the Chalk, are increasing in number.

The accounts of these wells (which will duly appear in the Memoirs of the Geological Survey) give the following indications of the position of the outcrop of the Chalk:—

At Easton Park, Framlingham, Beccles, and Norwich, the Chalk is covered directly by Crag or Drift.

At Woodbridge, Saxmundham, Bramfield, and Yarmouth a greater or less thickness of Lower Tertiary beds is present, and their boundary is probably three or four miles inland from these points.

At Hoxne, a few feet of 'green clay' lying directly on the Chalk may possibly be an outlier of the Reading Beds.

The Lower Tertiaries, thus outlined, possess no special interest, except that, being impervious clays, they cut off impure surface waters, and are easier to bore through than the loose sands, &c., overlying them.

The plane of the Chalk surface, whether under or beyond the Lower Tertiaries, is sufficiently uniform to render calculation of its depth in any part of the district an easy process. In the Bramfield boring, the latest of the series, the Chalk was reached at 48 feet below the Ordnance Datum, calculation from the three nearest points—Beccles, Framlingham, and Saxmundham—indicating $52\frac{1}{2}$ feet.

FRIDAY, AUGUST 27.

The following Reports and Papers were read:—

1. *Sixteenth and Concluding Report on the Exploration of Kent's Cavern, Devonshire.*—See Reports, p. 62.

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2. *Report on the Exploration of Caves in the South of Ireland.* See Reports, p. 209.

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3. *Report on the Viviparous Nature of the Ichthyosauria.* See Reports, p. 68.

4. *Report on the Carboniferous Polyzoa.*—See Reports, p. 76.

5. *Report on the 'Geological Record.'*—See Reports, p. 87.

6. *On the relation to be established between Coast-line Directions represented by Great Circles on the Globe, and the Localities marked by Earthquakes in Europe. By* Jos. P. O'Reilly, *C.E., Professor of Mining and Mineralogy, Royal College of Science, Dublin.*

This memoir, based on the following memoirs published by the Royal Irish Academy—

No. 1. 'Explanatory Notes and Discussion of the Nature of the Prismatic Forms of a Group of Basalts, Giant's Causeway.'—*R.I.Ac. Transactions XXII.* Nov. 1879.

No. 2. 'On the Correlation of Lines of Direction on the Earth's surface.' Read before the British Association (1878).—*R.I.Ac. Transactions XXI.* June 1879.

No. 3. 'On the Directions of Main Lines of Jointing observable in the Rocks about the Bay of Dublin.—*R.I.Ac. Proceedings. 2nd Ser. Vol. III.*

has for object to compare the earthquakes which have occurred during the years 1870–1878 with certain coast-line great circles of direction which traverse Europe, and which, originally traced by the author on a globe from the theoretical considerations contained in the memoir No. 2, have been transferred to the map of Europe. The memoir shows that certain relations of position do exist between the earthquake localities and the great circles. Thus, that between two of these great circles, called by him S.E. Sofala Coast-line Direction, and E. Coast of England Direction, there is defined a band of Europe in which lie the earthquake countries: Holland, district about Cologne, Westphalia, Rhine provinces, Odenwald district, Upper Rhine district, Switzerland, Tyrol, Upper and Lower Italy (nearly entirely), and Sicily; that is, the greater part of Europe markedly affected by earthquakes. That other great circles traverse them, forming bands equally remarkable as regards earthquake-movements, and, finally, that a very great number of earthquake localities are situated upon these great circle directions, or near their intersections. That there is evidence of these localities tending to develop into rectilineal directions, and, lastly, that outside Europe those great circles traverse districts markedly seismic in character, so that localities thus characterised, and situated on the same great circle of direction, present a certain connection, and may thus be brought into relation with it and with one another, as regards the earthquakes which may occur at them.

The author further proposes to define extents of globe-surface affected by earthquakes by considering them as being limited by such great circle directions traceable *à priori* on the globe, as proposed by him in his Memoir No. 2.

7. *On the Island of Torghatten. By* Professor W. J. Sollas, *M.A., F.R.S.E., F.G.S.*

The author described the results of a visit which he made to this island in July 1880.

The platform from which the peak of the island rises is a narrow plain of marine denudation, produced when the island was submerged 375 feet below its present level. The tunnel which traverses it is a sea-cave, excavated between two master-joints. The floor of the cave is covered with angular blocks of gneiss, which have fallen from the roof since the elevation of the cave-floor above the sea-level. The blocks have fallen far more rapidly at the entrances of the cave than in the interior, and, as a consequence, the roof rises from the middle towards each end of the tunnel, and so does the angular *débris*, which thus forms at each entrance a vast sloping mound. The vast quantity of fallen material is an interesting indication of what

has been accomplished by simple mechanical disintegration since the island was raised above the 375 feet level. The joints are the most important factors in denudation; excepting *moutonnée* faces, the author considers most of the bare rock faces which constitute the surface of Northern Norway as merely exposed joint planes. He has seen joints in the same rock, and having the same direction, extending from a few feet to over a thousand, and surface features in parallelism with them, from a facet not a yard across to precipices over a thousand feet high.

8. *On a Fragment of Mica Schist.* *By* Professor W. J. Sollas, *M.A., F.R.S.E., F.G.S.*

The author called attention to some appearances presented by a fragment of mica schist pointed out to him by Prof. Wm. Ramsay, Ph.D., while walking on the beach at Bodö, Norway. It is a tabular fragment, showing fine foliation laminæ, and traversed by an undulating vein of quartz. The undulations are very high and narrow, eight complete ones occurring along a distance of 10 inches in a straight line. The planes of foliation correspond to the bedding in the rocks of the neighbourhood (amongst which the same phenomenon was afterwards noticed). The folded quartz vein was originally straight, and cut across the laminæ at right angles; the folding must have been accomplished by compression of the schist at right angles to its foliæ; and by measuring the length of the quartz vein between two points, along its undulations (26 inches), and directly along its path (10 inches), one finds the amount of compression which has taken place (13 : 5). The argument is the same as that used by Dr. Sorby for the bed of quartzite folded in the slate of Devonshire.

9. *On the Geological Age and Relations of the Siwalik and Pikermi Vertebrate and Invertebrate Faunas.* *By* W. T. Blanford, *F.R.S., F.G.S.*

There is much similarity between the two collections of organic remains found in the Siwalik beds of Northern India and the strata of Pikermi in Attica. Both consist chiefly of mammalian remains, and amongst the forms represented there is an immense preponderance of large animals, that is, of mammals ranging from the size of a sheep to that of a large elephant, and a great deficiency of smaller species, the micro-mammalia (small rodents, bats, and insectivores) being almost unrepresented. In both, some bones of birds and reptiles and a few mollusca accompany the mammals. Finally, both have been generally referred to the Miocene epoch.

The Siwalik rocks are the upper strata of the Tertiary fringe, extending almost throughout the western and northern margins of the great Indo-Gangetic plain from Sind to Assam. The mass of the typical Siwalik fossils were found in the north-eastern Punjab, in the country between the Sutlej and Jumna, not far from Simla. The Tertiary beds here consist of—

Siwalik series	Upper.
	Middle.
	Lower (Náhan).
Sirmur series	Upper (Kasauli).
	Middle (Dagshai).
	Lower (Subathu).

These two series roughly correspond to Upper and Lower Tertiary, the best-defined horizon being that of Subathu, which is Nummulitic (middle or upper Eocene). The Siwalik fossils are from the upper and middle Siwaliks. None of the beds, except the Nummulitics of Subathu, contain marine fossils.

The rocks of Sind have recently been examined in detail, and the number of well-marked fossiliferous marine beds is much greater than in the sub-Himalayan region. The tertiary beds are thus sub-divided:—

Manchhar .	Upper . .	Pliocene (?).
	Lower . .	Upper miocene.

Gáj			Miocene.
Nari	Upper		Lower miocene (?).
	Lower		Oligocene.
Khirthar	Upper	}	Eocene.
	Lower		
Ranikot			

There is little doubt that the upper Manchhars, 5000 feet thick, correspond to upper and middle Siwalik.

The Gáj marine fauna is clearly Miocene, and rather upper than lower. My original view of the age, based chiefly on the *Echinodermata*, has been confirmed by Professor Martin Duncan's examination of the corals. A considerable number of mammalia have been found in the lower Manchhar beds, which pass downwards into the Gáj, and consequently cannot be older than upper Miocene.

Turning now to the Siwalik mammalian fauna, it is, I believe, with the addition of the species lately described by Rütimeyer and Bose, composed of 48 genera, comprising about 93 species, 23 genera being extinct, and 25 recent.

Amongst the fossil genera, 12 are unknown elsewhere; 4—*Pseudælurus*, *Amphicyon* (the occurrence of this in true Siwalik beds is doubtful), *Listriodon* and *Dorcatherium* are not known in beds later than Miocene in Europe, (*Pseudælurus* is found in Pliocene beds in America); 7 are Miocene and Pliocene of the recent genera; 9 range back in Europe to upper Miocene; 10 only to Pliocene; and 6 are only known elsewhere as living genera, or are found in Post-pliocene deposits. The very large proportion of species belonging to recent genera, like *Felis*, *Canis*, *Ursus*, *Elephas* (*Euelephas* and *Loxodon*), *Equus*, *Cervus*, *Bos*, *Antilope* and *Capra*, gives a singularly late aspect to the fauna.

Now, in the lower Manchhars of Sind no recent genera have been found except *Rhinoceros*, *Sus* and *Manis* (the generic identification of the latter being excessively doubtful), whilst *Dinotherium*, *Anthracotherium*, *Hyopotamus*, *Hyotherium*, and two new genera allied to *Merycopotamus* are found, none of which occur in the Siwaliks proper, and the species common to the two, excluding *Amphicyon*, are 8 in number, consisting of forms of *Mastodon*, *Rhinoceros*, *Acerotherium*, *Sus*, *Chalicotherium*, and *Dorcatherium*. There are 10 extinct genera to two recent (*Manis* being omitted as doubtful). There can be no question that the Manchhar fauna is decidedly older than Siwalik. But Manchhar cannot be older than upper Miocene, therefore Siwalik is Pliocene.

This conclusion is supported by the facts that out of six forms of reptiles sufficiently known to afford means of comparison, three are recent species; that amongst the four or five kinds of birds hitherto determined, one is probably identical with the living ostrich; and that all the land and fresh-water shells found are forms still existing. No such connexion with the recent fauna is known in any true Miocene rocks. The geological evidence is also in favour of a newer age for the fossiliferous Siwalik beds, as they form the upper members of the series; whilst the lower Manchhar rocks are at the base of formations which apparently represent the Siwalik series.

The singularly Miocene aspect of a portion of the Siwalik mammalian fauna finds a parallel in the case of Pikermi, in Attica; although the age of the one does not necessarily determine that of the other. The superb collection of remains made and admirably described by Professor Gaudry has constantly been classed as Miocene by the describer. It comprises 30 genera, of which 19 are extinct. Of these 30 genera, 13, besides *Helladotherium*, which is very possibly identical with *Sivatherium*, are found in the Siwaliks of India. The ruminants are in both very much more numerous in proportion to the other artiodactyle ungulates than is usual in Miocene strata; in the Siwalik, 33 against 10; in the Pikermi beds, 15 ruminants to 1 pig and 1 *Chalicotherium*. Nevertheless, out of 42 species found at Pikermi, no less than 15 are common to Miocene deposits in other parts of Europe. The connexion between Pikermi beds and typical Miocene is thus very similar to that between Siwalik and Manchhar beds.

But the Pikermi beds at their base contain three characteristically Pliocene

marine shells. The question is, are the marine shells or the mammalia to be accepted as deciding the age of the beds?

I agree so far with M. Gaudry, who at once accepts the evidence of the shells and considers the beds Pliocene. But he thinks the mammalia were of Miocene age, and that they died after the close of the epoch; their bones being subsequently washed down into the Pliocene formations. In this view I cannot concur, because bones decay when exposed to the atmosphere; and I can only conclude that the animals as well as the beds are of Pliocene age.

If these views be admitted, it will be seen that the evidence afforded by land mammalia as to geological age cannot be accepted with the same confidence as that of marine mollusca. It has long been found that the evidence of fossil plants is very liable to mislead; but in their case the difficulty is greater, because the remains do not always furnish equally clear proof of the relations of the fossils. There is, however, some reason to believe that the age of certain mesozoic beds in India, containing land or fresh-water reptiles and fishes, is not the same as that of strata characterised by the same animals in Europe; and generally land and fresh-water organisms do not seem so characteristic of age as marine fossils.

The explanation of the occurrence of so many Miocene forms in the Siwalik and Pikermi beds is very possibly the migration southwards of the palæarctic Miocene fauna. Some of the relations between the Siwalik animals and those of the peninsula of India at the present day, and the close connection between the fauna of Pikermi and that now found in Africa may be due to a further southern migratory movement in Post-pliocene times.[1]

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10. *On the Sandstones and Grits of the Lower and Middle Series of the Bristol Coalfield. By* EDWARD WETHERED, *F.G.S., F.C.S.*

The Bristol coalfield is noted for its series of grits and sandstones, and these probably have their equivalents, in the South Wales and Forest of Dean coalfields, as well as in that of Somersetshire. They serve as stratigraphical landmarks; and it was the object of the paper (1) to compare the grits of the above coalfield with one another, with a view of ascertaining whether there were distinguishing features which might enable them to be respectively determined, and assist in correlation. (2) To examine the chemical and physical conditions. (3) To note changes which occur when rocks are in contact with carbonaceous matter. The first point raised was the application of the term grit and sandstone. The author confirmed the statement of Mr. Sorby, in his presidential address to the Geological Society in 1880, to the effect that the Carboniferous sandstones were composed of angular grains. Of those examined by the author, the grains of the millstone grit were the least angular. It was also pointed out, that as rocks show such variation of coarseness in the same deposit, this could not be taken into consideration as a test for grit. It was therefore suggested that the term grit should be confined to those rocks which show angularity of grains, irrespective of coarseness; and the term sandstone to those which are composed of rounded grains (*i.e.* from which the angularity has been removed). In any case, the term grit must be more generally applied to Carboniferous rocks than has been the case hitherto.

Reference was then made to 'duns,' which was defined as those Carboniferous beds intermediate between grit or sandstone and clay. In mining operations, where the 'driving' of branches was by contract, questions arose between employer and employed, in the case of 'hard duns,' as to whether it is 'stone' or 'duns,' double price being paid for working in the former. It was also important for geological purposes, in the construction of sections, that there should be an easy and ready test for this determination. The author suggested that the scratching of glass would be a suitable one, which would represent a hardness of 7 for "stone" (that which scratches glass).

[1] For a fuller discussion of the subjects here mentioned, see *Manual of the Geology of India*, chap. xxiv. 1879.

The chief deposits of rock in the coalfield were then referred to in ascending order, commencing with the Millstone grit. Several samples of this, taken from Brandon Hill, gave from 97·4 to 98·5 per cent. of silica. In places it is used for brick-making, being mixed with the other material to increase the proportion of silica. It was pointed out that there were other beds higher up in the coal-measures which would do equally well, and in some cases better, for this purpose. The paper next referred to the 'Pennant grit.' There is considerable difficulty in defining the limits of this deposit, but it was certainly not 2000 feet thick, as some authors had stated. The paper places the thickness at about 970 feet; but the middle or Pennant series of coal measures, so called on account of the Pennant being so extensively developed in this division, was about 2000 feet thick, and this, probably, was the origin of the mistake regarding the thickness of the Pennant.

The 970 feet of rock above referred to as *the* Pennant grit, was only entitled to that name as a local distinction. It was nothing more than an extraordinary development of a coal measure grit; the 'Doxall grit' of the lower series, for instance, was quite as much a Pennant, if that term is to distinguish a certain class of rock.

After a careful examination of the rocks of the coalfield, the author had come to the conclusion that, owing to the great similarity of Carboniferous arenaceous rocks, occurring at different horizons, it was at the risk of serious error to rely upon them for correlation or stratigraphical landmarks. The proportion of silica could be sometimes used as a guide in determining one from another, but little reliance could be placed on it over a large area, as so many contained nearly about the same amount.

The author's analysis showed the first 50 feet of *the* Pennant to contain 90 per cent. of silica; but after this, for a considerable thickness, the proportion varied from 84 to 89 per cent.

The paper then referred to changes in the grits when in contact with carbonaceous matter. The author found that the proportion of alumina increased to the whole, and this mostly as a silicate. By comparing the analysis of duns and shale from the district with that of these rocks, the same constituents were found to be present, the great difference being in the greater proportion of alumina in duns and shale. As a rule, the latter beds always overlie seams of coal; but in cases where rock followed, the author found that as it neared the coal it became more fissile and argillaceous.

This change was ascribed to the action of carbonic acid gas, generated by decomposing vegetation on silicates. The analysis of the rocks given showed them to have been formed from the denudation of older silicate rocks, and the action of carbonic acid on such sediment would be to readily decompose all silicates with the exception of silicate of alumina, which would thus increase in proportion to the whole, and give rise to beds of the composition of duns and shale.[1] To this cause the author attributed the formation of the latter deposits, and contended that where they occur apart from carbonaceous matter is no proof that it was never there, and destroyed by decomposition.

SATURDAY, AUGUST 28.

The Section did not meet.

[1] The author was not dealing with the hydrocarbons which shales sometimes contain.

MONDAY, AUGUST 30.

The following Papers were read:—

1. *On a Raised Beach in Rhos Sili Bay, Gower. By* Professor PRESTWICH, *M.A., F.R.S.*

The author called attention to this as a remarkably fine instance of a raised beach having some peculiar and unusual features. It extends the whole length of the cliff in Rhos Sili Bay, facing the bay for a distance of 1½ miles. The top of the cliff consists of angular rubble of Old Red Sandstone, sometimes showing traces of rough stratification, and varying in thickness from 20 to 60 feet, overlying a beach 5 to 8 feet thick, consisting of well-rounded pebbles of various local, carboniferous and other rocks, and containing in places many *Turritella communis*, with a few *Nassa incrassata*, whereas in the more exposed raised beach at Mewslade before described by the author, the shells were *Patella vulgata*, *Littorina* (2 spec.) and *Purpura lapillus*. Under the beach, which is 8 to 12 feet above the present sea-level, there is another rubble of Old Red Sandstone fragments, with in one place blocks of a quartzose conglomerate, without stratification. Its thickness is not known. The author considered the upper rubble to have been washed down from the red sandstone hills which rise behind the beach by the water as the land rose after submergence, as described in the next paper, while to the lower bed of rubble he would ascribe a glacial origin.

2. *On the Geological Evidence of the temporary Submergence of the South-west of Europe during the early Human Period. By* Professor PRESTWICH, *M.A., F.R.S.*

The author stated that, in the long course of investigation of the Quaternary Beds in which he had been engaged, after referring the greater part of these beds to old river, sea, or glacial action, there remained a residual set of phenomena which could not be accounted for by any of these agencies. In few cases were these residual drifts of any stratigraphical importance, and in character and structure they differed greatly. They had been referred to various causes and to various times, but he thought they were all due to a common cause, that being the temporary submergence of the land after the formation of the latest of the river gravels, and after palæolithic man had spread over Europe and the greater part of England.

The submergence having been extremely slow and only temporary, while it is supposed that the emergence took place with greater rapidity and by intermittent movements, the effects of such changes lie as much in their denuding action on loose materials as in the formation of any deposits. The latter, in fact, are comparatively insignificant. They include, besides the 'Warp' of Trimmer, the 'Trail' of Fisher and the 'Head' of Godwin-Austen, and a series of loam and gravel beds of greater dimensions. These various drifts all have certain features in common. They are at their first origin *always angular*, they have their origin in the adjacent valley or hills, and are therefore *entirely local*, and they contain nothing but the *débris* of a *terrestrial surface*. The author showed that such deposits could not be referred either to river or marine action, or to rain-wash, snow or ice, and he gave reasons to show that they were in all probability the result of this *diluvial action*.

The author relied greatly on the evidence of the angular rubble (*Head*), overlying the raised beaches on both sides of the Channel, in which remains of the *mammoth*, *rhinoceros*, and other quaternary animals were not unfrequently found, and he further showed that in some instances *palæolithic flint implements* had been found in the same beds. In river valleys the same diluvial beds overlaid valley deposits with flint implements.

The author supposes that by this submergence *palæolithic man* was removed, at all events from all the lower lands, and the great extinct mammalia destroyed; and that the great superficial bed of gravel occupying the centre of our valleys, and which is the result of the final off-flow of the waters, defines and limits the

period of palæolithic man, while, with the alluvial beds, *neolithic man* (whether or not a descendant of palæolithic tribes, who may have escaped to higher levels, or whether introduced by migration) makes his appearance.

The author gave some reasons to show that the effects of this submergence are probably to be found over the greater part of Europe.

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3. *Proofs of the Organic Nature of* Eozoon Canadense. *By* Charles Moore, *F.G.S.*

Referring to the earlier history of the Laurentian beds and to the *Eozoon Canadense*, the author remarked on the pleasure he had experienced in having to assist Sir William Logan, the Director of the Canadian Geological Survey, in unpacking the large polished block of Laurentian limestone now in the Jermyn Street Museum, at the Bath meeting of the British Association in 1864.

After the paper then given by Sir William, the author ventured to express a doubt as to Eozoon being organic, and that he rather believed the beds to represent a mineralized or metamorphosed condition of rock-structure. That view he had continued to entertain, reserving to himself a change of opinion when it could be shown that there was continuity of life and other organisms found in the enormous thickness of 50,000 feet of rocks interposed between the Cambrian and the base of the Laurentian series, where Eozoon was found. That desideratum had yet to be attained.

After noticing the views of authors on both sides of the controversy, which had now extended to sixteen years, he remarked that his entering upon it was much by accident and under considerable disadvantages. Whilst others had possessed hundreds of cut and polished and other specimens for examination, he was possessed of only two slices, and two small blocks weighing but twelve ounces, both in their original conditions. From one of these he separated twenty grains, which on being decalcified revealed to him the presence of clear siliceous-looking fibroid growth. It was to be remembered that the material to be examined was scarcely more substantial than the motes or fibres seen floating in the sunbeam. Soon he obtained others of various colours, black, green, and olive, but so like the fibre of to-day that he suspected they must have got on the slide by some accident, and threw away many such specimens. At last he was encouraged by the presence of minute curled specimens whose genuineness and organic origin could not be doubted, and which could only be compared to the finest possible bits of polished golden wire. Their shapes first led to the supposition that they were the shells of a Laurentian annelid, but others followed of various forms, several of them tufted at their ends. One of the above is a very remarkable specimen. Seen under the microscope—for they are all invisible to the naked eye—it is formed of three round golden close-set coils. That this body is not a parasitic shell is evidenced by the fact that although when dry it is rigid, when moist both curved and curled specimens are flexible; they are substantial-looking objects as compared with others on the slide, and from their form and colour stand out conspicuously. What office they occupy if connected with the ancient animal has yet to be determined. They are possibly a portion of its fibroid growth. They are not unlike the pedicle to which the capsule of some Rhizopoda are attached, but in such a case they must have been devoured by the Eozoon, which is not probable.

In addition to the clear crystalline fibre previously mentioned, a close examination occasionally revealed another form not thicker than a spider's web, like mycelium growth of the present day.

Mention was made of palmated or dendritic-like serpentinous casts, of probably the canal system. Not unlike these, but differing in structure and much more delicate, were two fan-shaped bodies, with four long straight slender branches, equal in width throughout, of a brown colour, and springing from the same base; they appear to have been longer originally.

Although he might mention other points connected with Eozoon, he should conclude by remarking that amidst the material examined there occasionally

appeared bits of an amber-coloured or yellow semi-transparent film, and very rarely a round yellow circular body surrounded by a broad band, which he thought might possibly be Diatomaceæ. At another time he recognised a group of eleven much smaller forms, showing annular structure, which, under the circumstances, were most interesting and important; but whilst he was preparing to protect them by a cell-covering they dried, shrivelled up, and were lost. From what was said below he believed the latter to be ova or gemmules, and the coloured film possibly even an outer membrane, which hitherto had not been recognised in Foraminifera, through which the pseudopodial tubuli passed into the water.

The evidence thus adduced that the *Eozoon Canadense* is organic was to himself most convincing, and may be to the most sceptical; but should it be replied, 'It is true you have found traces of organic life in the Laurentian beds, but does it necessarily follow that they belong to Eozoon, and that it is a member of the animal kingdom?' to such objectors he had further confirmatory evidence of a most interesting character to offer. Amongst his duplicate fossils he had several specimens of *Nummulites lævigatus*, to which Dr. Carpenter and others consider Eozoon to be allied, and some smaller forms, possibly the young of that shell, but of which he was not quite certain. An examination of their structure showed the mycelium growth, fine as the finest spider's web, as in Eozoon, which appeared to be attached to the outer wall of the shell, and also, as in Eozoon, there appeared to be a membrane of the thinnest kind, through which the sarcode of the animal passed as pseudopodia. Transparent crystalline alga-like fibre was abundant, and in a partly decalcified specimen he had this standing out freely. Then he had separated from the shell closely-packed bands like a transparent network, or compressed together like a bit of recent woollen fibre. Very minute in size may be seen yellow worm-like ramifying fibres, which at first he thought might be parasitic fungi, but he was at present disposed to think they were too much mixed up with the animal sarcode to admit of this supposition.

There are, then, continual larger patches of yellowish branching ramified fibre, passing into broader or thinner bands, with network meshes, together with sarcode or protoplasmic matter, so that it appears as if the whole or the greater portion of the body of the Tertiary Nummulite was preserved. Scattered with these materials there are numerous amber-coloured granules, either single or in patches, which were supposed to be the gemmules or ova of the animal. There were also present pieces of the deep yellow, emerald green, and olive-coloured fibre, absolutely undistinguishable from those obtained from Eozoon. And lastly, in a mineralised specimen there were casts in iron pyrites of the tubes, cells, and chambers of the interior of the Nummulite, including many minute rounded spheres. These appear to represent, and to be identical with, the infiltrated serpentinous casts which are present under the same circumstances in Eozoon.

Rather from curiosity than expecting to make any favourable comparisons he had just examined the minute cells of Globigerina, brought up by the *Challenger* from the bottom of the Atlantic, and in them he also found traces of fibre and minute coloured fungi-like bodies, similar to those above referred to.

From the evidence thus adduced it will be seen that there is an actual parallelism between Eozoon and Foraminifera of more recent times, even to the minutest structure of the animals themselves. That the muscular fibre, the soft body, and possibly even the ova of a creature, which as yet reveals to us the earliest trace of animated existence, should have been preserved, is more than we could have anticipated. Although ages have passed away, and many miles of rock have intervened between it and its living representatives, it tells us that the same natural law which regulates all life has been continuous and permanent throughout.

Eozoon is at present happily named, but there seems no reason why, if we could discover beds still older than the Laurentians, we should not find earlier and still earlier dawns of animal life. Nor did he think that Eozoon lived alone, but that not only contemporary with it, but in the enormous thickness of beds intervening between it and the Cambrian rocks, connecting links of organic life may still reward the geological investigator.

4. *On some Pre-Cambrian Rocks in the Harlech Mountains, Merionethshire.* *By* Henry Hicks, *M.D., F.G.S.*

During an excursion into the Harlech Mountains in the summer of last year, I recognised, near the centre of the well-known anticlinal of Cambrian rocks, another group of rocks which appeared to me to underlie the former, and to be part of a pre-existing formation. On further examination, I noticed also that many of the fragments in the conglomerates at the base of the Harlech grits seemed to be identical with the rocks below, and to have been derived from some such pre-existing group. Subsequent microscopical examination of some of the fragments and of the underlying rocks tended strongly to confirm this view. In order, however, to satisfy myself more fully on this point, I revisited the area this summer, accompanied by my friends, Professor Hughes, Mr. Tawney, and Dr. R. D. Roberts, and the result has been to entirely confirm my previous conclusions. This discovery is of considerable importance, as it enables us to compare the thickness of the Cambrian rocks of North Wales more satisfactorily than has been hitherto possible with those of South Wales, and to realise more clearly the early physical conditions of the areas. Hitherto it seemed doubtful what the actual thickness of the Harlech group could be, and very different estimates have been given. It now becomes possible to give a perfectly correct estimate, and it is satisfactory to find that it approximates far more nearly with that made out in other Welsh areas than was previously supposed. The points where these older rocks come to the surface mainly occur along a line running nearly due N. and S. from Llyn-Cwmmynach to about two miles to the S.W. of Trawsfynnydd. Along this line the anticlinal of Cambrian rocks is considerably broken, and denudation has taken place to a very considerable extent. It is mainly in consequence of this that the pre-Cambrian rocks are exposed. The so-called intrusive felstones marked here on the survey maps are part of the pre-Cambrian group, and are not intrusive in the Harlech rocks. They are highly felsitic rocks, for the most part a metamorphic series of schists alternating with harder felsitic bands, probably originally volcanic ashes. They alternate with bands of purplish slates, which I once supposed might have been dropped amongst them by faults, but which I now think also belong to the pre-Cambrian group, as in the Pebidian rocks at St. Davids, and elsewhere. There are also some other exposures of the pre-Cambrian rocks in the adjoining areas, and one very interesting section was carefully examined by Professor Hughes and myself to the east of the Trawsfynnydd road between Caean Cochion and Penmaen, where the Cambrian conglomerates could be seen resting unconformably upon the older series, and large masses of the latter found plentifully in the conglomerates.

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5. *On the Fault Systems of Central and West Cornwall.* *By* J. H. Collins, *F.G.S.*

The author remarked that the faults and fault-systems of the district in question were very numerous, but that they were much more important, on account of their mineral contents, than for their mechanical effect in displacing the strata. After referring to the eight systems of faults—all being mineral veins—which were defined by Mr. Jos. Carne in 1818, the author brought forward evidence to prove that no fewer than fifteen distinct fault-systems of as many different ages could still be traced, all having been produced in post-carboniferous times. The fifteen systems were detailed as follows:—

1. Granite junction faults, the filling generally schorlaceous, and often stanniferous.
2. The older Elvan faults (the Little Elvan at Polgooth, &c.), more or less granitic in their filling.
3. The oldest tin lodes (Polgooth, &c.), heaved by the Great Elvan.
4. Newer Elvan faults (Polgooth, Great Elvan, &c.).

5. Newer tin lodes (Trevaunance, &c.), underlying northwards mostly.
6. Newest tin lodes (Trevaunance, Wheal Owles, &c.) mostly underlying southwards.
7. Older east and west copper lodes producing tin in depth (Dolcoath, &c.)
8. Older caunter copper lodes.
9. Older cross-courses.
10. Newer east and west copper lodes (Wheal Peevor).
11. Newer caunter copper lodes.
12. Newest copper lodes (Wheal Peevor).
13. Newer cross-courses and flucans.
14. Newest flucans and slides.
15. Alluvial faults.

The author showed that the older fissures were occupied either with quartz, together with tourmaline or stanniferous deposits (1, 3, 5), or else with granite and felsitic matter (2, 4); that the fissures of intermediate age were occupied chiefly by oxidised and sulphuretted copper ores near the surface, and by tin ores in depth (6, 7, 8, 10, 11, 12), or else by quartz, with small quantities of ores of nickel, cobalt, uranium, &c. (9); while the newer fissures contained only quartz, oxide of iron, galena, and blende (13, 14); while the newest of all contained little besides clay (15). In all (except 2 and 4) there are evidences of the partial mechanical infilling of open fissures.

In many cases the absolute amount of vertical displacement is small, in others it cannot be exactly ascertained, the most marked effects in this respect being produced by the cross-courses and cross-flucans (9, 13, 14). These cross-courses, &c., occur in great numbers between Hayle and Padstow, and owing to the fact that the downthrows are nearly always on the east sides of the respective faults, the total vertical displacement between these points cannot be less than 2000 feet, and is probably much more. In this way, older and still older rocks appear at the present surface as one proceeds westward.

The author concluded by briefly calling attention to the physical effects of these fault systems as developed in coast-lines and valleys.

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6. *On the Geology of the Balearic Islands.* *By* Dr. Phené, *F.S.A., F.G.S.*

In the two preceding years I have had the honour of drawing the attention of the Section to the magnificent effects of lime deposits in the Grottos of Antiparos, and to the almost mountainous dimension of the external deposits, called Pambuk Kalesi, at Hierapolis, in Anatolia.

There are some remarkable features in the geology of Minorca, in which that science has a beneficially sanitary effect, though it is probable that experience rather than scientific research produced in the first instance the effect, and then influenced popular opinion.

The island is geologically divided into two complete sections, which face each other in a continuous and very slightly deviating line from north-west to south-east. The southern portion is an almost uniform rock of Miocene formation, which occupies an area of more than half the island; the more northern begins on the east with a sea-coast of Devonian rocks running continuously to the north coast, with a mean breadth of three miles, succeeded by Lower Triassic beds, which crop up again further west, between which two portions is a broad Jurassic belt, curiously meandered by Upper Trias, and succeeded again by a broad field of Devonian formation. The large area of these various formations is found to be unhealthy for abode, though this may be entirely the result of latitude: but here at least they seem to contract the moist vapours which often hover over all the islands, while the rocky surface of the Miocene is much drier. All the large towns are erected on the latter, as Mahon, Cuidadella, Alayor, St. Cristobal; and Ferrerias is on the border.

In Majorca, to the north-west side of the island, the Jurassic formation rises

into a lofty cordillera, the highest peak of which attains an elevation of nearly 4400 feet above the sea. In this series of elevations are many eruptive rocks. The centre of the island is occupied by a fertile plain of rich soil on a base of Miocene (*moyen*) in the area of which are lacustrine beds. There are cretaceous beds, some abundant fossiliferous deposits, and some magnificent conglomerates of rich gold, red, and black colours. Some of the limestones exhibit the richest colours of marble.

This slight general sketch is sufficient probably to interest the practical investigator, and the Grotto de l'Homme Mort, with its abundant fossils, would alone well repay an examination.

There are some fine caves in Minorca, but the beautiful effects of the Cueva de la Hermita in the larger island tend speedily to make them forgotten.

The entrance to this cave is at a considerable elevation on the coast, which being attained the descent is easy. The dimensions are unusual, and the inspection occupies some hours. At intervals Bengal lights are burned, when a view opens which puts even the elegant tracery of Gothic and Moorish architecture aside. Long lines of light, straight, and uniform columns seem to multiply the effects of Westminster Abbey, while there is hardly a form, from magnificent organs, to pulpits, side chapels, and even mural monuments, that the eye does not figure to itself as realities. The progress of the stalactitic formation has evidently been arrested for centuries here, though still going on slightly in the caves in Minorca. With the exception of one or two small but good springs, there is no water on either island. Rain is collected in the winter in tanks and drawn up from wells. In some places, however, water is to be obtained by boring.

The author then gave some analyses of lignite, and referred to the metalliferous mines in Iviza and elsewhere.

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7. *On a Striated Stone from the Trias of Portishead.* *By* Professor W. J. Sollas, *M.A.*, *F.R.S.E.*, *F.G.S.*

This was a description of a striated fragment of carboniferous limestone from the Triassic breccia of Portishead. The striation was, however, not due to glacial action, but it is of the nature of 'slickenside.' The fragment was derived from the neighbourhood of the great fault which traverses the carboniferous rocks of the vicinity. It is interesting, since it shows that slickensided fragments, when occurring in a breccia, can be at once distinguished from true glaciated fragments, and could never deceive any experienced geologist. At the same time it might serve as a caution in receiving statements with regard to the finding of striated fragments which had not been submitted to competent authorities.

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8. *On the Action of a Lichen on Limestone.* *By* Professor W. J. Sollas, *M.A.*, *F.R.S.E.*, *F.G.S.*

The author referred to the presence of minute hemispherical pits sprinkled over the surface of many exposed limestone faces. These he showed were produced by the apothecia of a lichen, *Verrucaria rupestris*, as noticed by Sowerby. They are interesting as showing that the action of lichens is not purely conservative, but to some extent denuding, and also as proving that very similar cavities to those made by Cliona, which have been attributed to mechanical action, may be made by a vegetable which has no hard parts, and is almost as motionless as the stone on which it grows. Here all other agencies being eliminated, we have a case of excavation by purely chemical action.

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9. *On Sponge-spicules from the Chalk of Trimmingham, Norfolk.* *By* Professor W. J. Sollas, *M.A.*, *F.R.S.E.*, *F.G.S.*

This was an account of some sponge-spicules from the chalk of Trimmingham, Norfolk. They occur in association with flint nodules which have been incompletely

silicified. By treating the flints with dilute acid, a siliceous sediment remains, consisting of silicified tests of foraminifera, valves of entomostraca and crinoidal network, siliceous and glauconitic casts of foraminifera, and sponge-spicules. Amongst the siliceous casts of foraminifera is a dumbbell-shaped form, derived from two chambers of a Nodosaria, and mistaken by Zittel for a sponge-spicule. The sponge-spicules are snow-white and opaque by reflected light, but when mounted in Canada balsam so transparent as to be nearly invisible. They have become crypto-crystalline, give colours with polarised light, and have correspondingly acquired a higher refractive index than they possessed in the fresh state (Sollas, 'Ann. and Mag. Nat. Hist.' 1877, vol. xix. p. 20). They are eroded superficially, and sometimes covered with little hemispherical pits; occasionally dendrites of iron pyrites are seen shooting through their substance, the first stage of a replacement which is found completed in spicules from other deposits.

The spicules belong chiefly to Hexactinellid and Tetractinellid sponges. Of the latter forms Lithistids are frequent; they resemble the recent forms *Corallistes microtuberculatus*, *Lyidium torquilla*, *Discodermia polydiscus*, *Rhacodiscula asteroides*, and *Kaliapsis cidaris*; and are allied to the cretaceous genera described by Zittel under the names *Pachinion scriptum*, *Scytalia turbinata*, *Dorydermia dichotoma*, *Callopegma acaule*, and *Ragadinia rimosa*. The forms resembling Kaliapsis may be termed *Compsapsis cretacea*. The depth at which the living Lithistids most nearly related to the fossil ones have been found, varies from 74 to 375 fathoms.

Of other Tetractinellids there are stellate globules referable to *Tethya*, and scarcely distinguishable from those of *Tethya lyncurium*; these may be known as *Tethylites cretaceus*, a genus not in any way related to Zittel's Tethyopsis, as that is placed by him with *Tetilla cranium*. Calthrop-like spicules referable to Carter's *Dercitites Haldonensis* are common, also others probably related to Zittel's *Pachastrella primeva*. Tuberculated globules, similar to the characteristic globules of *Pachastrella geodoides*, Carter, occur. This living species was brought up from a depth of 292 fathoms, near St. Vincent's.

Ordinary geodid globules of various sizes are exceedingly common in various stages of decay, similar to those which the author has produced artificially in recent sponge-spicules by the action of caustic potash. With the globules were associated the usual geodid anchors, grapnels, and acerate spicules. Many are of the same forms as Carter's *Geodites Haldonensis*, and find their nearest ally in the existing *Geodia McAndrewi*, which has been dredged from 100 to 270 fathoms.

A club-shaped spicule, *i.e.* generally conical, rounded at the ends, and tuberculated all over, $\frac{1}{20}$-inch long, and $\frac{1}{100}$ broad where largest, is not unfrequent; it is quite unlike any existing spicule, and may be provisionally termed *Rhopaloconus cretaceus*.

Many other forms not mentioned here occur plentifully, and the number of different species found in the same flint is remarkable, but in this connection it may be remembered that Carter has described no less than seven entirely different species of sponge growing together on a thin fragment of *Lophohelia prolifera*, not quite two square inches in extent.

TUESDAY, AUGUST 31.

The following Reports and Papers were read:—

1. *Report on the Tertiary (Miocene), Flora of the Basalt of the North of Ireland.*—See Reports, p. 107.

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2. *Report on the Erratic Blocks of England, Wales, and Ireland.* See Reports, p. 110.

3. *List of Works on the Geology, Mineralogy, and Palæontology of Wales (to the end of* 1873). *By* W. WHITAKER, *F.G.S.*—See Reports, p. 397.

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4. *Sketch of the Geology of British Columbia. By* GEORGE M. DAWSON, *D.Sc., A.R.S.M., F.G.S., Asst. Director Geol. Survey of Canada.*

British Columbia includes a certain portion of the length of the Cordillera region of the west coast of America, which may be described as consisting here of four parallel mountain ranges running in a north-west and south-east bearing. Of these the south-western is represented by Vancouver and the Queen Charlotte Islands, and may be referred to as the Vancouver Range; while the next, to the north-east, is the Coast or Cascade Range, a belt of mountainous country about 100 miles in width. This is succeeded by the interior plateau of British Columbia, relatively a depressed area, but with a height of 3000 to 3500 feet. To the north-east of this is the Gold Range, and beyond this the Rocky Mountains proper, forming the western margin of the great plains of the interior of the continent.

Tertiary rocks, which are probably of Miocene age, are found both on the coast and on the interior plateau. They consist on the coast of marine beds, generally littoral in character, which are capped, in the Queen Charlotte Islands, by volcanic rocks. The interior plateau has been a fresh-water lake, in or on the margin of which, clays and sandstones, with occasional lignites, have been laid down. These are covered by very extensive volcanic accumulations, basaltic or tufaceous.

Cretaceous rocks from the age of the Upper and Lower Chalk to the Upper Neocomian, and representing the Chico and Shasta groups of California, occur on Vancouver and the Queen Charlotte Islands. Beds equivalent to the Chico group yield the bituminous coals of Nanaimo, while anthracite occurs in the somewhat older beds of the Queen Charlotte Islands. Within the Coast Range the Cretaceous rocks are probably for the most part equivalent in age to the Upper Neocomian. The Cretaceous rocks are of great thickness, both on the coast and inland, and include extensive contemporaneous volcanic beds.

The pre-Cretaceous beds have been much disturbed and altered before the deposition of the Cretaceous, and their investigation is difficult. On Vancouver Island, beds probably Carboniferous in age include great masses of contemporaneous volcanic material, with limestones, and became altered to highly crystalline rocks resembling those of parts of the Huronian of Eastern Canada. In the Queen Charlotte Islands also these beds probably occur; but an extensive calcareous argillite formation is there found, which is characterised by its fossils as triassic.

The Coast Range is supposed to be built up chiefly of rocks like those of Vancouver Island, but still more highly altered, and appearing as gneisses, mica-schists, &c., while a persistent argillaceous and slaty zone is supposed to represent the triassic argillites of the Queen Charlotte Islands.

The older rocks of the interior plateau are largely composed of quartzites and limestones; but still hold much contemporaneous volcanic matter, together with serpentine. Carboniferous fossils have been found in the limestones in a number of places. The triassic is also represented in some places by great contemporaneous volcanic deposits with limestones.

In the Gold Range, the conditions found in the Coast Range are supposed to be repeated; but it is probable that there are here also extensive areas of archæan rocks. Some small areas of ancient crystalline rocks supposed to be of this age have already been discovered.

The Rocky Mountain Range consists of limestones with quartzites and shaly beds, dolamites and red sandstones. The latter have been observed near the 49th parallel, and are supposed to be triassic in age. The limestones are, for the most part, Carboniferous and Devonian, and no fossils have yet been discovered indicating a greater age than that of the last-named period. On the 49th parallel, however, the series is supposed to extend down to the Cambrian, and compares closely with the sections of the region east of the Wahsatch, on the 40th parallel, given by

Clarence King. Volcanic material is still present in the Carboniferous rocks on the 49th parallel.

The oldest land has been that of the Gold Range, and the Carboniferous deposits laid down east and west of this barrier differ widely in character. The Carboniferous closed with a disturbance which shut the sea out from a great area east of the Gold Range, in which the red gypsiferous and saline beds of the Jura-trias were formed. In the Peace River region, however, marine triassic beds are found on both sides of the Rocky Mountains.

A great disturbance, producing the Sierra Nevada and Vancouver ranges, closed the Triassic and Jurassic period. The shore line of the Pacific of the Cretaceous in British Columbia lay east of the Coast Range, and the sea communicated by the Peace River region with the Cretaceous Mediterranean of the great plains. The Coast Range and the Rocky Mountains are probably in great part due to a post-Cretaceous disturbance, though the last-named range existed before the Cretaceous period in the Peace River region.

No Eocene deposits have been found in the province. The Miocene of the interior plateau is probably homologous with that of King's Pah-Ute lake of the 40th parallel. In the Pliocene epoch the country appears to have stood higher above the sea-level than at present, and during this time the fiords of the coast were probably worn out.

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5. *On the Post-Tertiary and more recent deposits of Kashmir and the Upper Indus Valley. By* Lt.-Col. H. H. Godwin-Austen, *F.R.S., F.G.S., &c.*

1. *Tertiary and Karewa Deposits of Kashmir.* Describes the Tertiary (Pleistocene) Hirpur Series on northern flank of the Pir Panjal, and gives measured section showing the changes of conditions that were going on during their deposition. Divides the post-tertiary Karewa deposits into an older series (Islamabad), and a newer in the low-level terraces toward Baramula. The successive lacustrine deposits of Kashmir owe their origin apparently to the gradual elevation of the gneissic axis of the Pir Panjal and Kajnag ranges to the south and south-west, which axis crosses the main drainage line of the Jhelum below Baramula.

2. *Alluvial deposits of Skardo.* Gives measured section of a portion of the above deposits near Kepchun, and shows the existence of two periods of glacial conditions in the Himalayas.

3. *Lacustrine deposits of the Indus Valley.* That from time to time the valley of the Indus has presented at different portions of its course a precisely similar appearance as we see now in the Pang-Kong Lake. That the coarse irregularly stratified gravels of Mulbi, Khurbo, &c., are older than the fine stratified silt of the Indus, near Lamayuru, and that they bear the same relation to them as those of the Chang-chingmo do to the Pang-Kong valley lacustrine beds.

4. *Glacial action.* On the very probable extension of glaciers from the Kajnag Range as far down as the Jhelum valley.

The absence of striæ marks on rocks in parts of the Himalayas that were once subjected to ice action, is no proof that such glacial conditions never existed; greater denudation than in Europe, and the greater distance in time, having obliterated such record and altered the valley sections.

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6. *Notes on the occurrence of Stone Implements in the Coast Laterite, south of Madras, and in high-level gravels and other formations in the South Mahratta Country. By* R. Bruce Foote, *F.G.S., of the Geological Survey of India.*

The author, after alluding to the area over which these chipped implements were known to occur in the Coast Laterite, when he read a paper to the Geological Society of London, in June 1868 (which area extended from the Palar river near Madras, nearly to the Kistna river), and pointing out that no such implement had

then been found south of the former river, proceeds to enumerate various localities within the Coast Laterite areas south of the Palar, in which he had been successful in discovering implements. He shows that as the material, quartzite, used in the more northerly parts is not found south of the Palar river, the southern makers had recourse to various other materials, generally chert, sometimes granular quartz rock of gneissic age. The presence of implements artificially made remains as then the sole positive proof of the existence of man. The new localities yielding implements are: 1. *Ninniyur,* 40 miles N.E. of Trichinopoly, in talus-débris of the Wodiarpalliam Laterite plateau. 2. *Vallam,* 7 miles south-west of Tanjore, several large flakes *in situ* in lateritic conglomerate. 3. *Shuragudi,* 16 miles south of Pudu-kotai, a large rude hatchet in lateritic débris close to the boundary of the great Shah-kotai laterite plateau. 4. *Madura,* in a coarse lateritic shingle-bed, apparently an outlier of the Sivaganga laterite area, several rude oval implements. Besides the above the author obtained a chert flake knife with one edge serrated, from a river gravel newer than the laterite at Tripatur in Madura district; also from the surface, associated with scattered lateritic débris, a chert-flake of arrowhead shape, and a well-shaped core of chert, believed to be the first of its kind found in South India.

The author then describes certain high-level, partly lateritic, gravels of fluviatile and lacustrine origin in the basins of the Gatprabha and Malprabha tributaries of the Kistna in the South Mahratta country, which yielded large numbers of fine quartzite implements of several types:—

Lastly, the occurrence is mentioned of well-shaped implements, chiefly of the pointed oval type, and made of hard siliceous limestone, in a great talus of limestone and Deccan trap blocks, cemented by calcareous tufa into a great breccia conglomerate. This occurs along the foot of the hills north of the Kistna, and west of Soorapoor, in the Nizam's territory. These implements were found washed out in gullies.

7. *On the Pre-Glacial Contours and Post-Glacial Denudation of the North-West of England. By* C. E. De Rance, *F.G.S.*

The country described is that lying between the Silurian mountains of North Wales and the Lake District, and bounded east by the Carboniferous hills of the Pennine chain. The plains of Lancashire and Cheshire lying at their feet are deeply covered with Glacial drift, reaching in one instance, near Ormskirk, a thickness of no less than 230 feet. The deep valleys of the Lake District had attained their present proportions before the Glacial epoch, during which the lake-basins were excavated—in the case of Windermere to a depth of 230 feet, or deeper than the English Channel between Boulogne and Folkestone, the bottom of the lake being 100 feet beneath the sea-level. In the valleys of the mountain country the marine Glacial deposits are not present, having been re-excavated out by later glaciation, where originally present. In Lancashire, Cheshire, and Flintshire the marine drift occupies an extensive area, and valleys like those of the Ribble and the Irwell, nearly 200 feet in depth, have been excavated in and through them. Occasionally the bottom of the valley is beneath the sea-level, pointing to the land being higher in pre-glacial times. A terrace of post-glacial deposits fringes the glacial area at, and often below, the sea-level, consisting of peat, with a forest at the base, resting on a marine post-glacial deposit. The peat bands are found beneath the sea-level to an extent, in one case, of about 70 feet, and it was pointed out that an elevation of this amount would connect Lancashire, Cheshire, and much of North Wales with the Isle of Man.

Section D.—BIOLOGY.

President of the Section—A. C. L. Günther, M.A., M.D., Ph.D., F.R.S., F.L.S.

DEPARTMENT OF ZOOLOGY AND BOTANY.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

Sixteen years ago, at the meeting of the British Association in Bath, the duty which I am endeavouring to discharge to-day was entrusted to my predecessor and old friend, the late Dr. John Edward Gray. In the address which he then delivered before this Section, he spoke on 'Museums, their Use and Improvement, and he who had devoted a whole lifetime to the formation and management of one of the greatest zoological collections in the world, was well qualified to give an opinion and advice on this subject. Indeed, when I read now what he then insisted on as a necessary change in the system of Museums, I feel compelled to pay a passing tribute to his memory.

Zoology, geology, botany were to him not distinct and independent studies; the views advanced by a Lamarck, by a Treviranus, viz., that our knowledge of these sciences would remain fragmentary and one-sided as long as they were not studied in their mutual relations, found in him one of the earliest advocates in this country. Against all opposition he tried to unite the Zoological and Palæontological collections in the British Museum, giving up this attempt only after having convinced himself of the impracticability of the scheme; and he readily joined the band of men who demanded that a Museum should be not merely a repository for the benefit of the professed student and specialist, but serve in an equal measure for the recreation of the whole mass of the people and for their instruction in the principles of Biology. This was the spirit in which he worked, and in the last years of his life he had the satisfaction of being able to say that there was no other collection in existence more accessible and more extensively used than the one under his charge.

I am encouraged to return to-day to the same subject, because I have daily the opportunity of observing that the public more and more comprehend the use of Museums, and that they appreciate any real improvements, however slight. Paragraphs, leaders, articles published in the public journals and periodicals, references made in speeches or addresses, questions put in the Houses of Parliament whenever an opportunity offers—all testify that the progress of Museums is watched with interest. Not long ago a Royal Commission entered deeply and minutely into the subject, and elicited a mass of evidence and information invaluable in itself, though you may differ from some of the conclusions and views expressed in their final report. Biological Science has made rapid strides: not only do we begin to understand better the relations of the varieties of living forms to each other, but the number of varieties themselves that have been made known has also been increased beyond all expectation, and the old repositories have everywhere been found too narrow to house the discoveries of the last forty years. Therefore you find that the United States, Austria, Prussia and Saxony, Denmark and Holland, France

and Great Britain have erected, or are building anew, their National Museums, not to mention the numerous smaller museums which are more or less exclusively devoted to some branch of Biological Science.

The purposes for which Museums are formed are threefold: 1. To diffuse instruction among, and offer rational amusement to the mass of the people; 2. To aid in the elementary study of Biology, and 3. To supply the professed student of Biology or the specialist with as complete materials for his scientific researches as can be obtained, and to preserve for future generations the materials on which those researches have been based.

Although every museum has, as it were, a physiognomy of its own, differing from the others in the degree in which it fulfils one or two or all three of those objects, we may divide museums into three classes, viz.: (1) National; (2) Provincial; and (3) Strictly educational museums: a mode of division which may give to those of this assembly who are not biologists an idea of what we mean by the term 'species.' The three kinds pass into each other, and there may be hybrids between them.

The museum of the third class, the *Strictly Educational* institutions, we find established chiefly in connection with universities, colleges, medical and science schools. Its principal object is to supply the materials for teaching and studying the elements and general outlines of Biology; it supplements, and is the most necessary help for, oral and practical instruction, which always ought to be combined with this kind of museum. The conservation of objects is subservient to their immediate utility and unrestricted accessibility to the student. The collection is best limited to a selection of representatives of the various groups or 'types,' arranged in strictly systematic order, and associated with preparations of such parts of their organisation as are most characteristic of the group. Collections of this kind I have seen arranged with the greatest ingenuity, furnishing the student with a series of demonstrations which correspond to the plan followed in some elementary textbook. This, however, is not sufficient for practical instruction; besides the exhibited permanent series, a stock of well-preserved specimens should be kept, for the express purpose of allowing the student to practise dissection and the method of independent examination; and in this latter I am inclined to include the method of determining to what order, family, genus, or species any given object should be referred. By such practice alone can the student learn to understand the relative value of taxonomic characters and acquire the elementary knowledge indispensable for him in the future. Finally, in the educational museum should be formed a series of all the animals and plants which are of economic value or otherwise of importance to man. The proposal to unite living and extinct forms in one series, which has been urged by eminent men with such excellent reasons, might be tried in the educational museum with great advantage to the student, as the principal objections that are brought forward against this plan being carried out in larger collections, do not apply here.

A museum which offers to the teacher and student the materials mentioned fulfils its object; its formation does not require either a long time or heavy expense; but the majority of these institutions outgrow in time their original limits in one or the other direction; and if such additions do not interfere with the general arrangement of the museum, they neither destroy its character nor do they add to its value as a strictly educational institution.

The principal aim of a *Provincial* Museum ought, in my opinion, to be popular instruction. I do not mean that it should be merely a place for mild amusement and recreation; but that it should rank equal with all similar institutions destined to spread knowledge and cultivate taste among the people. To attain this aim, it should contain an arranged series of well-preserved specimens, representing as many of the remarkable types of living forms as are obtainable; a series of useful, as well as noxious, plants and animals; of economic products obtained from the animal and vegetable kingdoms; and last, but not least, a complete and accurately named series of the flora and fauna of the neighbourhood. The majority of Provincial Museums with which I am acquainted are far from coming up to this ideal. One of the first principles by which the curator of such a museum should be guided

is to admit into his collection no specimen, unless it be well mounted, and a fair representative of its species. He has not the excuse of his colleague in charge of a large museum, who has to retain those monsters which are literally his *bêtes-noires*, viz., specimens to which a history is attached, and the removal of which would sooner or later be resented by some of his fellow-labourers. The only too frequent presence of such badly mounted specimens in Provincial Museums is not always the fault of the curator. The slender means with which he is provided are generally insufficient to encourage taxidermists to bestow the necessary amount of skill and time on their work. Besides, taxidermy is an art which depends as much on natural gift as drawing or modelling; and as long as we are obliged to be satisfied with receiving into our collections mediocre specimens, mediocre stuffers will take up taxidermy as a trade without there being one among them who is naturally qualified for it.

The direct benefit of a complete collection of the flora and fauna of the district in which the Provincial Museum is situated, is obvious, and cannot be exaggerated. The pursuit of collecting and studying natural history objects gives to the persons who are inclined to devote their leisure hours to it a beneficial training for whatever their real calling in life may be: they acquire a sense of order and method; they develop their gift of observation; they are stimulated to healthy exercise. Nothing encourages them in this pursuit more than a well-named and easily accessible collection in their own native town, upon which they can fall back as a pattern and an aid for their own. This local collection ought to be always arranged and named according to the plan and nomenclature adopted in one of those numerous monographs of the British Fauna and Flora in which this country excels; and I consider its formation in every Provincial Museum to be of higher importance than a collection of foreign objects.

The majority of Provincial Museums contain not only biological collections, but very properly, also, collections of art and literature. It is no part of my task to speak of the latter; but before I proceed to the next part of my address, I must say that nothing could more strikingly prove the growing desire of the people for instruction than the erection of the numerous Free Libraries and Museums now spread over the country. The more, the healthier their rivalry, the safer their growth will be, especially if they avoid depending on aid from the State, or placing themselves in the hands of a responsible minister; if they remain what they are—municipal institutions, the children and pride of their own province.

However great, however large a country or a nation may be, it can have, in reality, only one *National* Museum truly deserving of the name. Yours is the British Museum; those of Scotland and Ireland can never reach the same degree of completeness, though there is no one who wishes more heartily than I do that they may approach it as closely as conditions permit. The most prominent events in the recent history of the British Museum (to which I must confine the remainder of my remarks) are well known to the majority of those present:—that the question either of enlarging the present building at Bloomsbury, or of erecting another at South Kensington for the collections of Natural History, was fully discussed for years in its various aspects; that, finally a Select Committee of the House of Commons reported in favour of the expediency of the former plan; that the Standing Committee of the Trustees, than whom there is no one better qualified to give an opinion, took the same view; and that, nevertheless, the Government of the time decided upon severing the collections, and locating the Natural History in a separate building, as the more economical plan.

The building was finished this year at a cost of 400,000*l.* exclusive of the amount paid for the ground on which it is erected. It is built in the Romanesque or round-arched gothic style, terra-cotta being almost exclusively employed in its construction. It consists of a basement, ground floor, and two storeys, and is divided into a central portion, and a right and left wing. Its principal (southern) façade is 675 feet long. As you enter the portal you come into a cathedral-like hall, called the 'Index Museum,' 120 feet long, 97 feet wide, and 68 feet high; behind this there is a large side-lighted room for the British Fauna. On each side of the hall there is a side-lighted gallery, each 278 feet long, by 50 feet in width;

seven other galleries of various widths, and, therefore adapted for various exhibitions, join at right angles the long gallery of the ground floor. The first and second storeys are occupied by galleries similar to the main gallery of the ground floor.

The collections are distributed in this building thus:—The western wing is occupied by Zoology, the eastern by the three other departments, viz. the ground-floor by Geology, the first-floor gallery by Mineralogy, and the second-floor gallery by Botany. The central portion is, as mentioned above, divided into the room for British Zoology and into the 'Index Museum,' that is, 'an apartment devoted to specimens selected to show the type-characters of the principal groups of organized beings.' The basement consists of a number of spacious, well-lit rooms, well adapted for carrying on the different kinds of work in connection with such large collections.

There is no doubt that the building fulfils the principal condition for which it was erected, viz., space for the collections. The Zoological collections gain more than twice as much space as they had in the old building, the Geological and Mineralogical about thrice, and the Botanical more than four times. This increase of space will enable the keeper of the last-named department to bring the collections correlated with each other into close proximity, and to prepare a much greater number of objects for exhibition than was possible hitherto. The Mineralogical Department, already so admirably arranged in the old building, has now been supplied with the space requisite for a collection of rocks, with a laboratory and goniometrical room. Geology is now in a position to exhibit a great part of the Invertebrata, which hitherto had to be deposited in private studies, besides devoting one or two of the new galleries to a stratigraphical series. On the Zoological side we have been great gainers (not with regard to the proportion of space), but inasmuch as we were more impeded by the crowded state of our collections, than any of the other departments: we are enabled to avoid the exhibition of heterogeneous objects in the same room or gallery; mammals, birds, reptiles, fishes, mollusks, insects, echinoderms, corals, and sponges have each a smaller or larger gallery to themselves. With the exception of the specimens preserved in spirits, the study-series can be located in contiguity with, or at least, close vicinity to, the exhibition-series. There is ample and convenient accommodation for students; besides a spacious room, centrally situated, and arranged for the exclusive use of students, this class of visitors can be accommodated at four other different localities immediately adjoining the several branches of the collection.

I believe that some of the members of the British Association will feel somewhat disappointed that the Zoological and Botanical collections on the one hand, and the Palæontological on the other, continue to be kept distinct. Who will, who can, doubt that the two branches of Biological science would be immensely benefited by being studied in their natural mutual relations? and that Palæontology more especially would have made surer progress if its study had been conducted with more direct application to the series of living forms? But to study the series of extinct and living forms in their natural connection is one thing, and to incorporate in a museum the collection of fossil with that of recent forms, is another. The latter proposal, so excellent in theory, would offer in its practical execution so many and insuperable difficulties that we may well hesitate before we recommend the experiment to be tried in so large a collection as the British Museum. I have mentioned above that in a small collection such an arrangement may be feasible to a certain degree; but in a large collection you cannot place skins, bones, spirit-preparations, and stones in the same room, or, perhaps, in the same case, exposing them to the same conditions of light and temperature, without injuring either the one or the other. Each kind of those objects requires for its preservation special considerations and special manipulations; and by representing them in each of the several departments, you would have to double your staff of skilled manipulators with their apparatus, which means multiplying your expenses. Departmental administration generally, and especially the system of acquisition by purchase or exchange, would become extremely complicated, and could not be carried on without a considerably greater expenditure in time and money. Thus,

even if the old departmental division were abandoned for one corresponding to the principal classes of the animal kingdom, each of the new departments would still continue to keep, for consideration of conservation, those different kinds of objects, at least locally, separate. The necessity of this has been so much felt in the British Museum, that the Trustees resolved to store the spirit-specimens at South Kensington, in a building specially adapted for the purpose, and separated from the main building, as the accumulation of many thousand gallons of spirits is a source of danger which not many years ago threatened the destruction of a portion of the present building in Bloomsbury.

I could never see that by the juxtaposition of extinct and living animals the student would obtain particular facilities for study, or that the general public would derive greater benefit than they may obtain, if so inclined, from one of the numerous popular books; they would not be much the wiser if the *Archæopteryx* were placed in a passage leading from the reptile- to the bird-gallery. And it certainly cannot be said that the separation of living and extinct organisms so universally adopted in the old museums, has been a hindrance to the progress of our knowledge of the development of the organic world. This knowledge originated and advanced in spite of museums-arrangements. What lies at the bottom of the desire for such a change amounts, in reality, to this, that museums should be the practical exponents of the principle that zoologists and botanists should not be satisfied with the study of the recent fauna and flora, and that palæontologists should not begin their studies or carry on their researches without due and full reference to living forms. To this principle every biologist will most heartily subscribe; but the local separation of the various collections in the British Museum will not offer any obstacles whatever to its being carried out. The student can take the specimens (if not too bulky) from one department to the other; he may examine them in the gallery without interference on the part of the public; or he may have all brought to a private study, and, in fact, be in the same position with regard to the use of the collections as those who have charge of them. A plan which has been already initiated in the old building will probably be further developed in the new, viz., to distribute in the palæontological series such examples of important living types as will aid the visitor in comprehending the nature and affinities of the creatures of which he sees only the fragmentary remains.

With regard to the further arrangement of the collections in the new building, it has been long understood that the exhibition of all the species, or even the majority of them, is a mistake; and that, therefore, two series of specimens should be formed, viz., one for the purposes of advanced scientific study—the study-series; and the other comprising specimens illustrative of the leading points both of popular and scientific interest; this latter—the exhibition-series—being intended to supply the requirements of the beginner in the study of natural history, and of the public. As the zoological collections are better adapted for exhibition than the others, the following remarks refer principally to them. The bulk of our present exhibition-series is the growth of many years, and to convert it into one which fulfils its proper purpose, is a gradual and slow process; nor can it be expected to reveal its character until it has been removed into the new locality. The exhibition will probably be found more liberal than may be deemed necessary by some of my fellow-labourers; but if a visitor should, on leaving the galleries, 'take nothing with him but sore feet, a bad headache, and a general idea that the animal kingdom is a mighty maze without plan,' I should be inclined to believe that this state of bodily and mental prostration is the visitor's, and not the curator's fault. The very fact that the exhibition-series is intended for a great variety of people, renders it necessary to make a liberal selection of specimens, and I simply follow the principle of placing in it all those objects which, in my opinion, the public can understand and appreciate, and which therefore must contribute towards instruction. The public would receive but an inadequate return for keeping up a National Museum if they were shown, for instance, a dozen so-called 'types' of the family of parrots or humming birds; they require a good many more to see what Nature can produce in splendour and variation of colour, in grotesqueness of form; or to learn that whilst one of these groups of birds is spread all over the countries of the tropical

zone, the other is limited to a portion of a single continent. To render such an exhibition thoroughly useful, two additional helps are required, viz. a complete system of explanatory labels, and a popularly written and well-illustrated handbook, which should not only serve as a guide to the more important and interesting specimens, but give a systematic outline of the all-wise plan which we endeavour to trace in God's creation.

There is one part of the Museum which I intend to treat in a different manner from the rest, and that is the collection of British animals. For the same reasons for which I have in a former part of this address insisted on District Faunas being fully represented in Provincial Museums, I consider a complete exhibition of the British Fauna to be one of the most important objects of the National Museum. Its formation is, strange as it may appear to many of you, still a desideratum, and a task which will occupy many years. It will not be easy (especially when you are in danger of infringing an Act of Parliament), to form a complete series of British birds showing their changes of plumage, their young, their eggs, their mode of nidification; it is a long work to collect the larvæ and chrysalides of insects, and to mount the caterpillars with their food-plants; and we shall require the co-operation of many a member of the British Association when we extend the collection to the marine animals and their metamorphoses. But all the trouble, time, and labour spent will be amply repaid by the direct benefits which all classes will derive from such a complete British collection.

My time is becoming short, and yet I find that I am far from having completed the task I had set to myself. Therefore let me briefly refer only to a few points which of late have much agitated those who feel a direct or indirect interest in the progress of the National Museum.

In the first place we must feel deeply concerned in everything relating to the conservation of the collections. If the objects could speak to you as they do to those familiar with their history, many of them would tell you of the long hours of patient inquiry spent upon them; many might point with pride at the long pages written about them—alas! not always with the even temper which renders the study of natural science a delight and a blessing; others would remind you of having been objects of your wonder when you saw them depicted in scientific books, or in some household work; whilst not a few could tell you pitiful tales of the enthusiastic collector who, braving the dangers of a foreign climate, sacrificed health or life to his favourite pursuit. Collections thus obtained, thus cherished, representing the labours of thousands of men, and intended to instruct hundreds of thousands, are worth preserving, displaying, and cultivating. No cost has been spared in housing them; let no cost be spared in providing proper fittings to receive them, a sufficient staff to look after them, and the necessary books to study them.

What we chiefly require in a well-constructed exhibition-case is that it should be as perfectly dust-proof as possible, that it should lock well and easily, and yet that it should be of a light structure. Everyone who has gone through a gallery of our old-fashioned museums, must have noticed how much those broad longitudinal and transverse bars of the wooden frame of the front of a case interfere with the inspection of the objects behind them, hiding a head here, a tail there, or cutting an animal into two more or less unequal portions. Ill-constructed cases have brought zoological collections as much into bad repute as bad stuffers; and if it be thought that a pound could be saved in the construction of a case, that pound will probably entail a permanent expense of a pound a year. Now, all the requisites of a good exhibition case can be obtained by using metal wherever it can be substituted for wood; and, although its use is more expensive than that of wood, you will join with me in the hope that no mistaken desire of economy will prevail now as the time has arrived to furnish our priceless collections with adequate fittings.

Probably all of those present are aware that the formation of a Natural History Library has been urged almost from the very first day on which the removal of the Natural History collections to South Kensington was proposed. But the cost and extent of such a library have been very variously estimated. And I am

sorry to say that it is, I believe, owing to expressions of opinion on the part of those who ought to know better, that the cost of this library was considerably underrated when the removal to South Kensington was determined upon. We cannot blame the Government that they hesitated for years before they acceded to the pressing representations of the Trustees of the British Museum, to begin with its formation, when they were told by naturalists that the cost of such a library would be something between 10,000*l.* and 20,000*l.* I could hardly believe my eyes when I read only a few weeks ago in the leader of a weekly periodical specially devoted to science, 'that had the Trustees put aside a thousand a year for this purpose when it was first determined to remove the Natural History collections ten years ago, there would have been by this time in existence a library fully adequate to the purpose.' The writer must have either a very poor idea of the objects and work of a National Museum, or an imperfect knowledge of the extent of the literature of Natural History. 10,000*l.* might suffice to purchase a good ornithological library, and 1,000*l.* would purchase the annual additions to all the various branches of natural history; but the former sum would be much too small if the purchase of those works only were intended which are required for the technical work of naming animals, plants, fossils, and minerals. A better calculation was made by the Select Committee of the House of Commons on the British Museum in 1860, who stated that 'the formation of a Natural History Library would cost about 30,000*l.* at the present time' (1860). Considering that twenty years have elapsed since, and that this part of the literature has shown year by year a steady increase, we must put our estimate considerably higher than the writer of that article.

With the aid of some of my friends who know, from their daily occupation, the market value of Natural History works, I made a calculation some years ago, and we came to the conclusion that a complete Natural History Library will cost 70,000*l.*: and, unpalatable as this statement may be to those who have advocated the removal of the Natural History collections, and therefore, must be held responsible for this concomitant expense, it will be found to be true. It will be satisfactory to you to learn that the Government have at last sanctioned the expenditure of half that amount.

Now, in my opinion, such a library formed in connection with the National Museum, should not be reserved for the use of the officials, but I would recommend that it should be accessible to the general class of students in the same manner as any other part of the collections. It is for this reason that I wish to see it rendered as perfect as possible with respect to the older publications (many of which are getting scarcer year by year), as well as to the most recent. Whether or not a similarly perfect collection of Natural History books exists in some other place in London, is another question with which I am not concerned. The general National Library evidently ought to contain a perfect set of books on Natural History, irrespective of other claims; but to have Natural History collections in one place, and the books relating to them in another miles away, will produce as much inconvenience as is experienced by the person who puts the powder into the one barrel of his gun and the shot into the other.

If the British Museum (for the collections will remain united under this old time-honoured name, though locally separated) continues to receive that support from the Government to which it is justly entitled, I have no doubt that it will not only fulfil all the aims of a National Collection, but that it will be also able to give to the kindred provincial institutions the aid which has recently been claimed on their behalf. Under an Act of Parliament which was passed in the previous session, and which empowers the Trustees to part with duplicate specimens, several of those museums have already received collections of zoological objects. But I consider it my duty to caution those who are in charge of those Museums to be careful as to the manner in which they avail themselves of this opportunity. Well-preserved duplicates of the rarer and more valuable vertebrate animals are very scarce in the British Museum, the funds for purchase being much too small to permit the acquisition of duplicates. What we possess of this kind of duplicates are generally deteriorated specimens, and therefore ought not to be received by Pro-

vincial Museums. On the other hand, our invertebrate series, especially of Mollusks and Insects, will always offer a certain number of well-preserved duplicate specimens and a sufficient inducement for Provincial Museums to select their desiderata.

It has been suggested that, as the British Museum has correspondents and collectors in almost every part of the globe, and has, therefore, greater facilities for obtaining specimens than any other institution, it should systematically acquire duplicates, and form a central repository, from which Provincial Museums could draw their supplies. If the necessary funds to carry out this scheme were granted, I cannot see any objection to it on the part of the British Museum, which, on the contrary, would probably derive some benefit. But there is one, and in my opinion a very serious, objection, viz. that this scheme would open the door to the employment of curators of inferior qualifications; it would relieve the curator of a Provincial Museum of an important part of his duty, viz. to study for himself the requirements of his Museum, the means of meeting them, and to become well acquainted with the objects themselves. A curator who has to be satisfied with the mechanical work of displaying and preserving objects acquired, prepared and named for him by others, takes less interest in the progress of his Museum than he whose duty it would be to *form* a collection; he is not the person in whose charge the Museum will flourish.

In speaking of the claims of Provincial Museums on the National Museum, the kindred Colonial institutions should not be forgotten. We owe to them much of our knowledge of the Natural History of the Colonies; they are the repositories of the collections of the temporary and permanent surveys which have been instituted in connection with them, and they have concentrated and preserved the results of manifold individual efforts which otherwise most likely would have been lost to science. The British Museum has derived great benefit from the friendly relations which we have kept up with them; and, therefore, they are deserving of all the aid which we can possibly give them, and which may lessen the peculiar difficulties under which they labour in consequence of their distance from Europe.

I am painfully aware that in the remarks which I have had the honour of making before you, I have tried the patience of some, and not satisfied the expectations of others. But so much I may claim:—that the views which I have expressed before you as my own are the results of many years' experience, and therefore should be worthy of your consideration; and that I am guided by no other desire than that of seeing the Museums in this country taking their proper place in regard to Biology, and as one of the most important aids in the instruction of the people.

The following Reports and Papers were read:—

1. *Report on the present State of our Knowledge of the Crustacea. Part V. By* C. Spence Bate, *F.R.S.*—See Reports, p. 230.

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2. *Report of a Committee for conducting Palæontological and Zoological Researches in Mexico.*—See Reports, p. 254.

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3. *Report of the 'Close Time' Committee.*—See Reports, p. 257.

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4. *Report of the Committee on the Zoological Station at Naples.*—See Reports, p. 161.

5. *On the Development of Lepidosteus.* *By* F. M. Balfour, *F.R.S.*, *and* W. N. Parker.

The paper contained an account of the observations of the authors on some preserved material supplied to them by Al. Agassiz. The following are the chief points to which attention was called:—

(1) The segmentation is complete as in the Sturgeon, but the segments at the lower pole of the ovum soon fuse into a single mass which forms the yolk sack.

(2) The epiblast is divided into a nervous and an epidermic layer.

(3) The cerebro-spinal cord is formed, from a solid keel-like thickening of the epiblast, as in Teleostei and Petromyzon. In this respect Lepidosteus contrasts strikingly with the Sturgeon, in which the cerebro-spinal cord is formed in the usual vertebrate fashion.

(4) There is a pronephros (head-kidney) of the Teleostean type.

The authors further called attention to the structure and homologies of a provisional suctorial disc in front of the mouth, of which Agassiz has already given an account.

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6. *On the Classification of Cryptogams.*[1] *By* Alfred W. Bennett, *M.A.*, *B.Sc.*, *F.L.S.*, *Lecturer on Botany at St. Thomas's Hospital.*

In the most recent classification of cryptogams, that by Sachs, in the 4th ed. of his 'Lehrbuch,' he divides thallophytes (including characeæ) into four classes of equal rank, Protophyta, Zygosporeæ, Oosporeæ, and Carposporeæ. It is proposed in the present paper to retain Sachs's class of Protophyta for the lowest forms of vegetable life; but to restore the primary division of the remainder of thallophytes into fungi and algæ, as being more convenient to the student and at least as much in accordance with probable genetic affinities.

As regards minor points, the characeæ are removed altogether from thallophytes, and again constituted into a separate group of the first rank; the myxomycetes are regarded as presenting a low type of structure, scarcely raised above the protophyta, and not exhibiting true sexual conjugation; volvox and its allies are removed from the zygosporeæ to the oosporeæ; and the phæosporeæ are separated off as a distinct order from the fucaceæ.

The thallophytes are therefore first of all divided into three primary classes:—Protophyta, Fungi, and Algæ. The protophyta are divisible into two subclasses, *Protomycetes* and *Protophyceæ*. The protomycetes consist of a single order, the Schizomycetes, of which saccharomyces is regarded as an aberrant form. The protophyceæ are composed of the protococcaceæ (including palmellaceæ and scytonemaceæ), nostocaceæ, oscillatorieæ, and rivularieæ. The *Myxomycetes* are treated as a supplement to the protophyta. The fungi are made up of three sub-classes, employing in the main the same characters as Sachs, but, in their terminology, using the syllable 'sperm' instead of 'spore.' The first division, the *Zygomycetes* (or zygospermeæ achlorophyllaceæ), is composed of the mucorini only (including the piptocephalidæ). The second, the *Oomycetes* (or oospermeæ achlorophyllaceæ), comprises the peronosporeæ and saprolegnieæ (including the chytridiaceæ). The third, the *Carpomycetes* (or carpospermeæ achlorophyllaceæ), is made up of the uredineæ, ustilagineæ, basidiomycetes, and ascomycetes, the lichenes being included in the last as a sub-order. The algæ are arranged under three corresponding sub-classes. The *Zygophyceæ* (or zygospermeæ chlorophyllaceæ) is made up of the following orders:—Pandorineæ, hydrodictyeæ, confervaceæ (under which the pithophoraceæ may possibly come), ulotrichaceæ, ulvaceæ, botrydieæ, and conjugatæ (the last comprising the desmidieæ, diatomaceæ, zygnemaceæ, and mesocarpeæ). The *Oophyceæ* (or oospermeæ chlorophyllaceæ) include the volvocineæ, siphoneæ (with the nearly allied dasycladeæ),

[1] Published *in extenso* in the *Quarterly Journal of Microscopical Science*, for Oct. 1880.

sphæropleaceæ, œdogoniaceæ, fucaceæ, and phæosporeæ. The *Carpophyceæ* (or carpospermeæ chlorophyllaceæ) is made up of the coleochæteæ and florideæ.

The CHARACEÆ constitute by themselves a group of primary importance. The MUSCINEÆ are unchanged, comprising the *Hepaticæ* and *Musci* (including sphagnaceæ). In VASCULAR CRYPTOGAMS it is proposed to revert to the primary distinction into *Isosporia* and *Heterosporia*, as most in accordance with probable genetic affinities. The isosporia consist of the filices (including ophioglossaceæ), lycopodiaceæ, and equisetaceæ. The heterosporia comprise the rhizocarpeæ and selaginellaceæ. In the terminology of the heterosporia the inconvenience and incorrectness are pointed out of the use of the terms 'macrospore' and 'macrosporangium'; and it is proposed to call the two kinds of spores and their receptacles respectively *microspore, megaspore, microsporangium,* and *megasporangium*; or better, in reference to their sexual differentiation, *androspore, gynospore, androsporangium*, and *gynosporangium*.

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7. *A Reformed System of Terminology of the Reproductive Organs of Thallophytes.*[1] *By* ALFRED W. BENNETT, *M.A., B.Sc., F.L.S., Lecturer on Botany at St. Thomas's Hospital, and* GEORGE MURRAY, *F.L.S., Assistant, Botanical Department, British Museum.*

After giving illustrations of the present chaotic state of cryptogamic terminology, the authors proceed to state that the object they have kept in view is to arrive at a system which shall be symmetrical and in accordance with the state of knowledge, and which shall at the same time interfere as little as possible with existing terms. A few new terms are introduced, but the total number is greatly reduced.

In the 4th edition of his 'Lehrbuch,' Sachs defines a 'spore' as 'a reproductive cell produced directly or indirectly by an act of fertilisation,' reserving the term 'gonidium' for those reproductive cells which are produced without any previous act of impregnation. The practical objections to this limitation of terms are pointed out, and it is proposed to restore the term *spore* to what has been in the main hitherto its ordinary signification, viz., *any cell produced by ordinary processes of vegetation and not by a union of sexual elements, which becomes detached for the purpose of direct vegetative reproduction.* The spore may be the result of ordinary cell-division or of free cell-formation. In certain cases (*zoospores*) its first stage is that of a naked mass of protoplasm; in rare instances it is multicellular, breaking up into a number of cells (*polyspores*, composed of *merispores*, or breaking up into *sporidia*). Throughout thallophytes the term is used in the form of one of numerous compounds expressive of the special character of the organ in the class in question. Thus, in the protophyta and mucorini we have *chlamydospores*; in the myxomycetes, *sporangiospores*; in the peronosporeæ, *conidiospores*; in the saprolegnieæ, oophyceæ, and some zygophyceæ, *zoospores*; in the uredineæ, *teleutospores, æcidiospores, uredospores,* and *sporidia*; in the basidiomycetes, *basidiospores*; in the ascomycetes (including lichenes), *conidiospores, stylospores, ascospores, polyspores,* and *merispores*; in the hydrodictyeæ, *megaspores*; in the desmidieæ, *auxospores*; in the volvocineæ and mesocarpeæ, *parthenospores*; in the siphoneæ and botrydieæ, *hypnospores*; in the œdogoniaceæ, *androspores*; in the florideæ, *tetraspores* and *octospores.* The cell in which the spores are formed is in all cases a *sporangium.*

In the terminology of the male fecundating organs very little change is necessary. The cell or more complicated structure in which the male element is formed is uniformly termed an *antheridium*, the ciliated fecundating bodies *antherozoids* (in preference to 'spermatozoids'). In the florideæ and lichenes, the fecundating bodies are destitute of vibratile cilia; in the former case they are still usually termed 'antherozoids,' in the latter 'spermatia,' and their receptacles 'spermogonia.' In order to mark the difference in structure from true antherozoids, it is proposed to designate these motionless bodies in both cases *pollinoids*;

[1] Published *in extenso* in the *Quarterly Journal of Microscopical Science,* for October 1880.

the term 'spermogonium' is altogether unnecessary, the organ being a true antheridium.

A satisfactory terminology of the female reproductive organs presents greater difficulties. The limits placed to the use of the term spore and its compounds require the abandonment of 'oospore' for the fertilised oosphere in its encysted stage anterior to its segmentation into the embryo. The authors propose the syllable *sperm* as the basis of the various terms applied to all those bodies which are the immediate result of impregnation. It is believed that this will be found to supply the basis of a symmetrical system of terminology which will go far to redeem the confusion that at present meets the student at the outset of his researches. For the unfertilised female protoplasmic mass, it is proposed to retain the term *oosphere*, and to establish from it a corresponding series of terms ending in *sphere*. The entire female organ before fertilisation, whether unicellular or multicellular, is designated by a set of terms ending in *gonium*.

In the zygomycetes and zygophyceæ, the conjugated *zygospheres*, or contents of the *zygogonia*, constitute a *zygosperm*; in the oomycetes and oophyceæ the fertilised *oosphere*, or contents of the *oogonium*, is an *oosperm*; in the carpophyceæ the fertilised *carposphere*, or contents of the *carpogonium*, constitutes a *carposperm*. In this last class the process is complicated, being effected by means of a special female organ which may be called the *trichogonium* (in preference to 'trichogyne'). The ultimate result of impregnation is the production of a mass of tissue known as the *cystocarp* (or 'sporocarp'), within which are produced the germinating bodies which must be designated *carpospores*, since they are not the direct results of fertilisation. Any one of these bodies which remains in a dormant condition for a time before germinating is a *hypnosperm*. In the cormophytes (characeæ, muscineæ, and vascular cryptogams) the fertilised *archesphere*, or contents of the *archegonium*, is an *archesperm*. In the proposed system zygosperm will replace Strasburger's 'zygote,' and the 'gametes' of the same writer will be zygospheres, his 'zoogametes' or 'planogametes' being *zoozygospheres*.

In the basidiomycetes, ascomycetes, and some other classes, it is proposed to substitute the term *fructification* for 'receptacle,' for the entire non-sexual generation which bears the spores.

A list is appended of the terms in more frequent use which are disused in the proposed system.

FRIDAY, AUGUST 27.

The following Report and Papers were read:—

1. *Report of the Committee for the investigation of the Natural History of the Island of Socotra.*—See Reports, p. 212.

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2. *On the French Deep-sea Exploration in the Bay of Biscay. By* J. GWYN JEFFREYS, *LL.D., F.R.S.*—See Reports, p. 378.

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3. *Further Remarks on the Mollusca of the Mediterranean. By* J. GWYN JEFFREYS, *LL.D., F.R.S.*

At the Bradford meeting of the Association in 1873, I made some remarks on the Mollusca of the Mediterranean, and gave a list of those species which had not yet been noticed, as Atlantic, being then 222 in number. Since that time many of the species have been discovered in the Atlantic, or been ascertained to be varieties of other well-known Atlantic species. This list will be found in pages 113 to 115 of the Report for 1873. I will now give a list of those Mediterranean species

which are also Atlantic or varieties of other species, on the authority of the Marquis de Monterosato, the Marquis de Folin, Dr. Fisher, the Rev. Mr. Watson, and myself.

BRACHIOPODA.

Argiope cordata, *Risso.*
Thecidium mediterraneum, *Risso.*

CONCHIFERA.

Pleuronectia lævis, *Jeffreys.* A monstrosity of Pecten similis.
Mytilus minimus, *Poli.*
Nucula convexa, *J.* = N. ægeensis, *Forbes*; young.
Leda oblonga, *J.* = L, micrometrica, *Seguenza.*
—— subrotunda, *J.* = L. minima, *Seg.*
Solenella cuneata, *J.* (Malletia).
Venus cygnus, *Lamarck* = V. nux, *Gmelin.*
Pecchiolia insculpta, *J.* (Verticordia).

GASTROPODA.

Emarginula adriatica, *O. G. Costa.*
Trochus scabrosus, J. = T. gemmulatus, *Philippi.*
Fossarus costatus, *Brocchi.*
Rissoa caribæa, *D'Orbigny.*
—— rudis, *Ph.*
—— maderensis, *J.*
Cæcum chiereghinianum, *Brusina*—C. glabrum, *Montagu*; variety.
Vermetus triquetra, *Bivona.*
Scalaria Cantrainei, *Weinkauff.*
Odostomia polita, *Biv.*
—— tricincta, *J.*
—— fasciata, *Forb.*
Eulima microstoma, *Brus.*
—— Jeffreysiana, *Brus.*
Natica Dillwynii, *Payraudeau.*
—— marmorata, *H. Adams.*
Solarium pseudoperspectivum, *Brc.*
Xenophora mediterranea, *Tiberi.*
Cerithium costatum, *Da Costa.*
—— elegans, *De Blainville.*
Triton seguenzæ, *Aradas and Benoit* = T. nodifer, *Lam.*; var
Lachesis Folineæ, (*Delle Chiaje*) *Ph.*
Cassidaria echinophora, *Linné*; probably C. tyrrhena, *Chemnitz* is a variety.
Defrancia hystrix, *De Cristofori* and *Jan.*
Pleurotoma pusilla, Scacchi = P. multilineolata, *Deshayes*; var.
Cypræa physis, *Brc.* ?
Utriculus striatulus, *J.*
Akera fragilis, *J.*
Diphyllidia lineata, *Otto.*
—— pustulosa, *Sc.*
Total, 41 species.

This reduces the number of supposed exclusively Mediterranean species from 222 to 181; and it must be borne in mind that the Atlantic Nudibranchs and Cephalopods have never been completely worked out. Philippi's list of Mediterranean Nudibranchs and Verany's list of Mediterranean Cephalopods amount to 58 out of the above residue of 181. When further researches by dredging have been made in the North Atlantic, I believe the difference between the Mollusca in that extensive ocean and in the Mediterranean will be still more diminished, if it do not in time altogether disappear.

SATURDAY, AUGUST 28.

The Department did not meet.

MONDAY, AUGUST 30.

The following Report and Papers were read:—

1. *Report on Accessions to our Knowledge of the Chiroptera during the past two years* (1878–1880). *By* G. E. DOBSON, *M.A., M.B., &c.*—See Reports, p. 169.

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2. *The Cruise of the 'Knight Errant.'* *By* Professor Sir C. WYVILLE THOMSON, *F.R.S.*

This paper was mainly physical, and related to the temperature-conditions of the sea-bed lying between our northern coasts and the Faroe Isles. Certain parts of this submarine district had been ascertained by the author and Dr. Carpenter during the cruises of the *Lightning* and *Porcupine* in 1868 and 1869 to have remarkably different temperatures; and they had distinguished these parts by the names 'cold area' and 'warm area.' It had been inferred from observations in H.M.S. *Challenger* that the phenomenon depended in this and similar cases upon the interruption of the flow of the undercurrent by a raised submarine ridge.

The author, being desirous of working out this problem more completely, applied to the Admiralty for the use of a surveying vessel; and, in compliance with his request, the *Knight Errant* was placed this summer at his disposal. Two sectional lines of soundings were taken at an average intermediate distance of ten miles. The following were the results:—

FIRST LINE.

No.	Depth in fathoms	Bottom Temperature. Fahr.	No.	Depth in fathoms	Bottom Temperature. Fahr.
1	88	49° 5′	8	405	46° 5′
2	178	49° 6′	9	355	43° 8′
3	400	45° 8′	10	270	43° 5′
4	560	45° 2′	11	335	41° 0′
5	540	46° 0′	12	245	41° 8′
6	300	47° 5′	13	120	47° 5′
7	305	46° 5′	14	130	46° 0′

SECOND LINE.

No.	Depth in fathoms	Bottom Temperature. Fahr.	No.	Depth in fathoms	Bottom Temperature. Fahr.
1	370	35° 5′	7	285	45° 8′
2	375	31° 0′	8	255	48° 0′
3	375	31° 0′	9	460	46° 0′
4	285	32° 5′	10	202	48° 2′
5	210	47° 0′	11	145	49° 5′
6	260	47° 5′	12	93	50° 0′

A serial temperature-sounding was also taken in 540 fathoms.

The weather, however, was unfavourable; and the author expressed a hope that the exploration might be renewed next summer, in order to examine the fauna on the northern slope of the Scotch coast, which had been proved to be very abundant and peculiar.[1]

3. *On the Relation of the Lepidoptera of Great Britain to those of other Countries. By* Captain H. J. Elwes.

The author pointed out that Great Britain is very poor in the number of species of butterflies, compared with almost any part of the Palæarctic region, but is relatively much more rich in moths, though deficient in some of the day-flying genera. Secondly, that the number of species in any part of Europe is proportionately greater near the south coast, though in France, Italy, and Austria, the numbers are much increased by a large proportion of purely Alpine forms. Thirdly, that the generic character of the butterflies remains unchanged throughout North Asia and North America, though in the former case there is a considerable infusion of Oriental forms in Japan and North-east Asia; whilst in the southern and warmer parts of the United States are found many species belonging to neotropical genera mixed up with species belonging to the dominant Palæarctic groups. But on the whole, the butterflies of the United States, and especially of Colorado, are very nearly allied to those of Europe, and the differences are not enough to separate the two regions, so far as butterflies are concerned.

4. *On the Double Malar Bone. By* Professor G. Rolleston, *M.D., F.R.S.*

5. *On the Classification of Rodents. By* Professor G. Rolleston, *M.D., F.R.S.*

6. *On the 'Drumming' of the Snipe. By* Captain W. V. Legge, *R.A., F.L.S., F.Z.S.*

The writer spoke of the interest taken in the snipe's breeding habits, owing to its being such a favourite bird, and to the fact of its disposition during the nesting season being demonstrative and excitable, the very opposite of what it is at other times. Reference was made to the extraordinary noise made by the bird when flying over its nest or young, to the variety of opinion as to its origin, and to Herr Meeves's paper, published in the 'Proceedings of the London Zoological Society,' 1858, in which a very ingenious theory was propounded, setting forth the idea that the noise was made by the vibration of the outer tail feather. Herr Meeves's reasons for his theory were alluded to, and his experiment with the tail feathers of the snipe, tied to a wire and stick, and moved through the air, was repeated by the writer, who also gave a description of the feathers in the bird's tail. Mr. Hancock's paper, in the 'Catalogue of the Birds of Northumberland and Durham,' was then reviewed, and its author's opinion that the 'drumming' was made alone by the wings commented upon, as well as his refutation of Herr Meeves's theory noticed. In support of Mr. Hancock's argument that the isolated tail-feather attached to the wire but feebly represents the same feather in its place in the living bird, the writer demonstrated that though a peculiar noise, somewhat like the vibrations heard during the 'drumming' of the snipe, could be made when the feather was moved to and fro with a radius of motion of 4 or 5 feet, it was not possible to produce the same sound when the feather was moved with a radius of only $3\frac{1}{4}$ inches, which would be all that it would have in the living bird. Mr. Hancock's statements that the bird descended with firm-set tremulous wings was, however, contradicted by

[1] The original paper has been published in full in *Nature* for September 2, 1880, p. 405.

the writer, who went on to relate his own experiences, and gave an account of observations he had made this summer on the bogs of Central Wales. An instance was mentioned in which a snipe, on a still evening in June last, had drummed for fifty minutes, flying round the writer's head, and this very favourable opportunity had enabled the closest observations to be made. The actions of the bird were minutely described, and it was shown that in the downward sweep of the bird, when it 'drummed,' the wings were beaten very rapidly with regular strokes, and the vibratory sounds falling on the ear at the time were *exactly coincident with those strokes;* at the same time the tail was spread out like a fan, and the writer contended that the sound was produced by the air being driven by the wings at each stroke through the rigid feathers of the tail, as when they are blown on with with quick puffs, emitted from the lips, a sound resembling the 'drumming' noise is heard. Were the sound produced alone by the wings, it would be heard continually throughout the bird's aërial course; but as this is not the case, it can only be due to the combined action of the wings and tail, when the latter is spread.

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7. *On the Migration of Birds, and Messrs. Brown and Cordeaux's Method of obtaining Systematic Observations of the same at Lighthouses and Lightships. By* ALFRED NEWTON, *M.A., F.R.S.*

Citing a passage from an article by the Duke of Argyll ('Contemporary Review,' July 1880, p. 1), the author met with a direct denial the Duke's assertion that of 'the army of the birds' it may be said that 'it cometh not with observation,' pointing out that all we know of the migration of birds arises from observation, and all we do not know, from the want of it; remarking, also, that if it were not for observation, we should not know that birds migrate at all, and that it is by renewed observation alone that we can hope to know more of their migratory movements. The author then proceeded to describe briefly the nocturnal passage of birds, as noticed by himself at Cambridge for the past seventeen years, and urged the importance of similar but more systematic observations at other stations. Remarking upon the especial advantages of lighthouses and lightships for this purpose, he called attention to the successful attempt made last year, with the sanction of the authorities of the Trinity House and the Commissioners of Northern Lights, by Mr. J. A. Harvie Brown and Mr. Cordeaux, to obtain a series of observations from the lighthouses and lightships on the coasts of Scotland and the east coast of England, the results of which were embodied by those gentlemen in a Report (printed in the 'Zoologist' for May 1880), and showed that returns were received from two-thirds of the English stations, and as regards the Scottish, from about two-thirds of those on the west, and one-half of those on the east coast, thus evincing the intelligent interest taken by the men there employed in the inquiry. This single report naturally did not throw any new light on the subject; but it would be contrary to all experience if a series of such reports did not do so, and he therefore urged the Association to lend its countenance to the renewed attempts which Messrs. Brown and Cordeaux were making, and to encourage with its approval those gentlemen and their fellow-workers—the men of the lighthouses and lightships—who would best answer the question, whether knowledge of the subject 'cometh not with observation.'

TUESDAY, AUGUST 31.

1. *Exhibition of some of the Zoological Reports of the 'Challenger' Expedition. By* P. L. SCLATER, *M.A., Ph.D., F.R.S.*

Mr. Sclater, on behalf of Sir C. Wyville Thomson, who was unable to attend the meeting, laid on the table specimen copies of the following reports on the zoological results obtained during the voyage of H.M.S. 'Challenger.' These reports would ultimately form the first volume of the 'Zoology' of the expedition, which would very shortly be ready for general issue:—

List of 'Challenger' Reports.

Report on the Development of the Green Turtle (*Chelone viridis, Schneid.*) By William Kitchen Parker, F.R.S.

Report on the Bones of Cetacea collected during the Voyage of H.M.S. 'Challenger,' in the years 1873–6. By William Turner, M.B., F.R.S., &c.

Report on the Shore Fishes procured during the Voyage of H.M.S. 'Challenger,' in the years 1873–6. By Albert Günther, M.A., M.D., F.R.S., &c

Report on the Brachiopoda dredged by H.M.S. 'Challenger' during the years 1873–6. By Thomas Davidson, F.R.S., F.L.S., &c.

Report on the Pennatulida dredged by H.M.S. 'Challenger' during the years 1873–6. By Professor Albert V. Kölliker, F.M.R.S., &c., &c.

Report on the Ostracoda dredged by H.M.S. 'Challenger' during the years 1873–6. By George Stewardson Brady, M.D., F.L.S.

Report on Certain Hydroid, Alcyonarian, and Madreporarian Corals procured during the Voyage of H.M.S. 'Challenger,' in the years 1873–6. By H. N. Moseley, M.A., F.R.S., &c.

The following Papers and Report were read:—

2. *On the Classification of Birds. By* P. L. SCLATER, *M.A. Ph.D., F.R.S.*

THE author commenced by a short account of the principal modes of arranging the Class of Birds put forward by naturalists since the days of Linnæus, who, in the first edition of the 'Systema Naturæ' (1766), had divided them into six orders (table i). This had been quite superseded in 1817 by the more natural system propounded by Cuvier in his 'Règne Animal' (table ii.) which, with slight modifications, had met with almost universal adoption—at least in this country—up to a recent period. In spite of the assaults made upon it by the anatomists and osteologists of Germany, and notwithstanding, in particular, the advanced views of Nitzsch, put forward in his various writings (see table iii.) and especially in his celebrated 'Pterylography,' in which the mode of arrangement of the feathers on the bodies of birds was first proposed to be taken into consideration, the Cuvierian system had held its own, and in fact was still in use by the great majority of ornithologists. About twelve years ago, however, Prof. Huxley had taken up the subject of the classification of Birds in his usual zealous and original way, and from quite a new point of view. Prof. Huxley, treating birds mainly from their bones and as if they were extinct animals of which these parts of their structure only were known, had proposed an entirely new plan of arrangement (table iv.), based mainly upon the characteristic variations of the palatal bones, which had passed almost unnoticed by previous writers. The author, who had long been dissatisfied with the Cuvierian system, which with certain modifications he had employed up to 1872, had in that year been constrained to consider the whole subject in order to decide what arrangement should be adopted in the 'Nomenclator Avium Americanarum' (a joint work by Mr. O. Salvin and himself), then ready for publication. Having, as already stated, long

entertained serious doubts as to the validity of the Grayian arrangement, especially as to the groups associated together in the orders Grallæ and Anseres, he had been pleased to find available an alternative which had the sanction of high authority. Whatever might be the case as regards the four principal divisions of the Carinatæ, based solely upon the palatal structure, and upon which sundry more or less effective criticisms had been made by subsequent investigators, there seemed to be no doubt to the author that the minor divisions of the Huxleyan system, by which the whole class of birds was divided into about 23 families, constituted a much more natural system than that of Cuvier and his followers. Prof. Huxley had commenced his system with the lowest and most reptilian birds, and had ended it with the highest and most specialized. But it seemed to the author that by exactly reversing this arrangement he would obtain a scheme which would not very far deviate from that which he had previously employed for the first three orders, and would offer many improvements on the Grayian system in the remaining ones. Such a scheme had accordingly been promulgated in the Introduction to the 'Nomenclator' and had been used in that work. In the various subsequently issued editions of the 'List of Vertebrated Animals in the Zoological Society's Gardens' a nearly similar arrangement had been followed. A certain amount of adhesion having been secured to this system, the author had been recently induced to devote some labour to its improvement and development. As now elaborated it did not profess to be in any respects original, except as regarded certain small details on points to which he had devoted special attention. The arrangement was in fact simply that of Huxley reversed, with slight modifications consequent upon the recent researches of Parker and Garrod on the anatomy and osteology of little known forms.

The author then proceeded to explain further the 'Systema Avium' thus advocated, as shown in the subjoined table, in which the approximate number of known species was added after each order.

ORDERS OF EXISTING BIRDS.

Subclass Carinatæ (10,121 species).

		Species			Species
I.	Passeres	5,700	XIII.	Gallinæ	320
II.	Picariæ	1,600	XIV.	Opisthocomi	1
III.	Psittaci	400	XV.	Hemipodii	24
IV.	Striges	180	XVI.	Fulicariæ	150
V.	Accipitres	330	XVII.	Alectorides	60
VI.	Steganopodes	60	XVIII.	Limicolæ	250
VII.	Herodiones	130	XIX.	Gaviæ	130
VIII.	Odontoglossæ	8	XX.	Tubinares	100
IX.	Anseres	180	XXI.	Pygopodes	65
X.	Palamedeæ	3	XXII.	Impennes	20
XI.	Columbæ	355	XXIII.	Crypturi	40
XII.	Pterocletes	15			

Subclass Ratitæ (18 species).

XXIV.	Apteryges	4	XXVI.	Struthiones	4
XXV.	Casuarii	10			

In submitting this arrangement, as one which on the whole he was disposed to regard as the best to be adopted after many years' study of the Class of Birds, the author observed that it should be recollected that, although a linear system is an absolute necessity for practical use, it could never be a perfectly natural one. It would always be found that certain groups were nearly equally related to others in different places in the linear series, and that it was a matter of difficulty to decide with which of the allied forms they were best located. But, a linear arrangement being an absolute necessity, it became our duty to endeavour to make it as natural as possible.

TABLE I.

Classification of LINNÆUS (1766).

I. Accipitres
II. Picæ
III. Anseres
IV. Grallæ
V. Gallinæ
VI. Passeres

TABLE II.

Classification of CUVIER (1817).

I. Oiseaux de Proie { Diurnes, Nocturnes }
II. Passereaux
- a { Dentirostres, Fissirostres, Conirostres, Tenuirostres }
- b Syndactyles

III. Grimpeurs
IV. Gallinacés
V. Echassiers
VI. Palmipèdes

TABLE III.

Classification of NITZSCH (1829).

I. AVES CARINATÆ.

A. A. c. aereæ.
1. Accipitrinæ
2. Passerinæ
3. Macrochires
4. Cuculinæ
5. Picinæ
6. Psittacinæ
7. Lipoglossæ
8. Amphibolæ

B. A. c. terrestres.
1. Columbinæ
2. Gallinaceæ

C. A. c. aquaticæ.
1. Alectorides
2. Gruinæ
3. Fulicarinæ
4. Herodiæ
5. Pelargi
6. Odontoglossæ
7. Limicolæ
8. Longipennes
9. Nasutæ
10. Unguirostres
11. Steganopodes
12. Pygopodes

II. AVES RATITÆ.

TABLE IV.

Classification of HUXLEY (1867).

I. SAURURÆ (*Archæopteryx*)

II. RATITÆ

1. *Struthio*
2. *Rhea*
3. *Casuarius et Dromæus*
4. *Dinornis*
5. *Apteryx*

III. CARINATÆ.

a. DROMÆOGNATHÆ
- I. *Tinamidæ*

b. SCHIZOGNATHÆ
1. Charadriomorphæ
2. Geranomorphæ
3. Cecomorphæ
4. Spheniscomorphæ
5. Alectoromorphæ
6. Peristeromorphæ

c. DESMOGNATHÆ
1. Chenomorphæ
2. Amphimorphæ
3. Pelargomorphæ
4. Dysporomorphæ
5. Aetomorphæ
6. Psittacomorphæ
7. Coccygomorphæ

d. ÆGITHOGNATHÆ.

1. Celeomorphæ
2. Cypselomorphæ
3. Coracomorphæ

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3. *Notes on the French Deep-sea Exploration in the Bay of Biscay. By* the Rev. A. M. NORMAN, *F.L.S.* Incorporated with Dr. Gwyn Jeffreys' Paper on the same subject.—See Reports, p. 378.

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4. *Report on the Marine Zoology of South Devon.*—See Reports, p. 160.

DEPARTMENT OF ANTHROPOLOGY.

CHAIRMAN OF THE DEPARTMENT—F. W. RUDLER, F.G.S. (Vice-President of the Section).

THURSDAY, AUGUST 26.

The CHAIRMAN delivered the following Address:—

AFTER an absence of more than thirty years the British Association has again assembled in South Wales. To the student of anthropology it is always refreshing to visit a province of the United Kingdom in which the inhabitants still retain, in large measure, their peculiarities of language and of race. But in that part of the Principality which we are now visiting, these characteristics have for many generations been growing fainter and fainter. In fact the local circumstances which render a meeting of the British Association possible are precisely those circumstances which tend to obliterate ethnical distinctions. The material prosperity of any locality naturally draws towards it a stream of immigration from less prosperous districts, and thus produces an artificial mixture of population. If the influx into Swansea had come only from the agricultural parts of Wales, there would have been comparatively little ethnical confusion; but, as a matter of fact, all the large towns of Glamorganshire, such as Swansea, Cardiff, and Merthyr, have received strong accessions to their population from various parts of England and of Ireland. The anthropologist would, therefore, be ill advised if he resorted to any of these flourishing centres for the purpose of studying the typical Welshman.

Glamorganshire probably contains, at the present time, more than one-third of the entire population of Wales; yet the area of the county is but little more than one-ninth of the total area of the Principality.[1] This concentration of the people is due, directly or indirectly, to the gigantic development of those mining and

[1] At the last census the population of Glamorganshire was 397,859, and that of the entire Principality only 1,216,775. The area of Glamorganshire is estimated to be about 547,070 acres, while the total area of Wales is said to be 4,722,323 acres.

metallurgical industries which are centred in this county. The temptation of high wages, offered in seasons of prosperity, has attracted hither a large number of settlers from different parts of the United Kingdom. Occasionally, too, recourse has been had to the technical skill of foreigners; and thus ethnical elements have been introduced, to a limited extent, from outside the British Isles. Even the typical industries of the district have not always been of indigenous growth. Colonel Grant-Francis, who acted at the Swansea meeting of 1848 as secretary to the ethnological sub-section, the equivalent of our present anthropological department, has written an interesting history of Welsh copper-smelting,[1]—an industry which is pre-eminently characteristic of the Swansea district. It appears from this historical sketch that the art was introduced in the reign of Queen Elizabeth by 'that very honest and skilfull man,' Ulricke Frosse, and his 'Right worshipfull and very singuler good M'r," Thomas Smith. The very names mentioned here as those of the founders of the industry indicate a commingling of nationalities which is typical of what so frequently occurs in our great manufacturing districts, to the undeniable benefit of society at large, but nevertheless to the embarrassment of the anthropologist.

It is worth while noting that the movement of population towards South Wales has been mainly determined by the geological structure of the district. It was the occurrence of coal that originally tempted Ulricke Frosse to bring his cargo of copper-ore across from Cornwall to be smelted in the Vale of Neath; and it is still the working of coal which maintains the local industries and supports the vast population of Glamorganshire. The connection between the geological structure of a district and the social and ethnic characteristics of its inhabitants has been recognized by no one more clearly than by the distinguished geologist who is presiding over the present meeting of this Association.[2]

Had it not been for the abundant occurrence of coal and iron ores in South Wales, the land of Morganwg might have been at the present day a peaceful agricultural district. But even then the ethnologist would have found it hard to study the racial characteristics of its native population aloof from all disturbing influences. For it is matter of history that as far back as the twelfth century South Wales was colonized at several points by Flemish settlers. Most of these colonists settled in Pembrokeshire, where they helped to disturb the ethnology of the county, and ultimately obliterated from certain districts most of the Welsh characteristics.[3] Their Low-Dutch speech would be readily assimilated with the English, while it refused to blend with the Welsh, and thus the English-speaking people remained sharply separated from their Welsh-speaking neighbours—the 'Englishry' distinct from the 'Welshery.' Possibly the Teutonic element may be partly due to an earlier settlement of Northmen.[4] Camden mentions the English-speaking part of Pembrokeshire under the name of *Anglia Transwalliana*, and everyone knows that it is still referred to as 'Little England beyond Wales.'

It is generally supposed that what took place in Pembrokeshire was repeated on a smaller scale in the promontory of Gower, and thus it happens that we still find 'Flemings' in the immediate neighbourhood of Swansea. The English-speaking people of Gower,[5] composed probably of Norse, Flemish, Norman, and English elements, were so distinct from the neighbouring Welsh, that the districts

[1] 'The Smelting of Copper in the Swansea District, from the Time of Elizabeth to the Present Day.' Printed from the *Cambrian* for private circulation. Swansea: 1867.

[2] One of the most charming chapters of Professor Ramsay's *Physical Geology and Geography of Great Britain* is devoted to this subject, and especially to the Ethnology of Wales.

[3] 'In the swaynes and labourers of the countrey you may often trace a Flemish origin.' So wrote the observing antiquary, George Owen, two centuries and a half ago, as quoted by Fenton in his *Historical Tour through Pembrokeshire*.

[4] *The Land of Morgan*. By G. T. Clark, Esq. *Archæological Journal*, vol. xxxiv. 1877, p. 18. On the occupation of Gower by the Danes, see *A History of West Gower*, by the Rev. J. D. Davies, M.A., 1877, Part 1, chap. ii. p. 16.

[5] The vocabulary of Gower is said to contain no exclusively Flemish elements. See Dr. Latham's *English Language*, vol. i. 4th ed. p. 424.

inhabited by the two nationalities are often distinguished in old records as *Gower Anglicana* and *Gower Wallicana*.[1] But, I believe that the barriers between the two peoples have in modern times been considerably relaxed, and that there is at the present day more or less intermixture of blood.

Apart, however, from all foreign admixture, there is still in Glamorganshire, especially in the outlying districts, a very large proportion of the population who may be fairly regarded as typically Welsh. If we can strip off all extraneous elements which have been introduced by the modern settler and the mediæval Fleming, possibly also by the Norman baron and even the Roman soldier, we may eventually lay bare for anthropological study the deep-lying stratum of the population—the original Welsh element. What then are the ethnical relations of the typical man of South Wales?

Nine people out of every ten to whom this question might be addressed would unhesitatingly answer that the true Welsh are Celts or Kelts.[2] And they would seek to justify their answer by a confident appeal to the Welsh language. No one has any doubt about the position of this language as a member of the Keltic family. The Welsh and the Breton fall naturally together as living members of a group of languages to which Professor Rhys applies the term *Brythonic*, a group which also includes such fossil tongues as the old Cornish, the speech of the Strathclyde Britons, and possibly the languages of the Picts and of the Gauls. On the other hand, the Gaelic of Scotland, the Irish, and the Manx arrange themselves as naturally in another group, which Professor Rhys distinguishes as the *Goidelic* branch of the Keltic stock.[3] But does it necessarily follow that all the peoples who are closely linked together by speaking, or by having at some time spoken, these Keltic languages, are as closely linked together by ties of blood? Great as the value of language unquestionably is as an aid to ethnological classification, are we quite safe in concluding that all the Keltic-speaking peoples are one in race?

The answer to such a question must needs depend upon the sense in which the anthropologist uses the word Kelt. History and tradition, philology and ethnology, archæology and craniology, have at different times given widely divergent definitions of the term. Sometimes the word has been used with such elasticity as to cover a multitude of peoples who differ so widely one from another in physical characteristics that if the hereditary persistence of such qualities counts for anything, they cannot possibly be referred to a common stock. Sometimes, on the other hand, the word has been so restricted in its definition, that it has actually excluded the most typical of all Kelts—the Gaulish Kelts of Cæsar. According to one authority, the Kelt is short; according to another tall: one ethnologist defines him as being dark, another as fair; this craniologist finds that he has a long skull, while that one declares that his skull is short. It was no doubt this ambiguity that led so keen an observer as Dr. Beddoe to remark, nearly fifteen years ago, that 'Kelt and Keltic are terms which were useful in their day, but which have ceased to convey a distinct idea to the minds of modern students.'[4]

[1] *The History and Antiquities of Glamorganshire.* By Thomas Nicholas, M.A. 1874, p. 47.

[2] Whether this word should be written Celt or Kelt seems to be a matter of scientific indifference. Probably the balance of opinion among ethnologists is in the direction of the former rendering. Nevertheless it must be borne in mind that the word 'celt' is so commonly used nowadays by writers on prehistoric anthropology to designate an axe-head, or some such weapon, whether of metal or of stone, that it is obviously desirable to make the difference between the archæological word and the ethnological term as clear as possible. If ethnologists persist in writing 'Celt,' the two words differ only in the magnitude of an initial, and when spoken are absolutely indistinguishable. I shall therefore write, as a matter of expediency, 'Kelt.' It may be true, as Mr. Knight Watson has pointed out, that there was originally no justification for using the word 'celt' as the name of a weapon, but it is too late in the day to attempt to oust so deeply-rooted a word from the vocabulary of the archæologists.

[3] *Lectures on Welsh Philology.*' By John Rhys, M.A., 2nd edition, 1878, p. 15.

[4] *Mem. Anthrop. Soc. Lon.*, vol. ii. 1866, p. 348.

No anthropologist has laboured more persistently in endeavouring to evoke order out of this Keltic chaos than the late Paul Broca. . . . Permit a momentary pause at the mention of one who has so recently and so unexpectedly been lost to science. By Broca's death anthropology has suffered a loss which is literally irreparable, and it would ill become us who are assembled in this department to mention his name at such a time without a passing expression of emotion and a tribute of respect. Let me remind you that it was Broca who not only founded, but untiringly sustained that brilliant school of Parisian anthropologists, who have done so much within the last twenty years to advance the Science of Man. From the Société d'Anthropologie there sprang, a few years ago, the École d'Anthropologie, an institution officially recognised by the State for the cultivation of anthropological studies. It was in the laboratory of this school, with its admirably arranged museum, and its convenient lecture theatre, that Broca, surrounded by his pupils, pursued his labours in so devoted a spirit as at last to over-reach the limits of his strength. Unsparing of himself in work, an eloquent speaker and a powerful writer, at once an anatomist, a scholar, and a mathematician—Broca, exercised a singular fascination over the younger men who gathered around him, and thus the work which he initiated will not be allowed to perish. Fortunately, he secured in Dr. Topinard a colleague who fully caught the spirit of the master; but still the master's loss can only be expressed by the one word which I employed before—irreparable!

What, let us ask, was the opinion of this distinguished anthropologist on the Keltic question?[1] Professor Broca always held that the name of Kelt should be strictly limited to the Kelt of positive history—to the people, or rather confederation of peoples, actually seen by Cæsar in Keltic Gaul—and, of course, to their descendants in the same area. Every schoolboy is familiar with the epitome of Gaulish ethnology given by Julius in his opening chapter. Nothing can be clearer than his description of the tripartite division of Gaul, and of the separation between the three peoples who inhabited the country—the Belgæ, the Aquitani, and the Celtæ. Of these three peoples the most important were those whom the Romans called *Galli*, but who called themselves, as the historian tells us, *Celtæ*. The country occupied by the Keltic population stretched from the Alps to the Atlantic in one direction, and from the Seine to the Garonne in another; but it is difficult to find any direct evidence that the Kelts of this area ever crossed into Britain. Broca refused to apply the name of Kelt to the old inhabitants of Belgic Gaul, and as a matter of course he denied it to any of the inhabitants of the British Isles. Writing as late as 1877, in full view of all the arguments which had been adduced against his opinions, he still said: 'Je continue à soutenir, jusqu'à preuve du contraire, ce que j'ai avancé il y a douze ans, dans notre première discussion sur les Celtes, savoir, qu'il n'existe aucune preuve, qu'on ait constaté dans les Iles-Britanniques l'existence d'un peuple portant le nom de Celtes.'[2]

Nevertheless, in discussing the Keltic question with M. Henri Martin, he admitted the convenience, almost the propriety, of referring to all who spoke Keltic languages as *Keltic* peoples, though of course he would not hear of their being called Kelts. 'On peut très-bien les nommer les peuples celtiques. Mais il est entièrement faux de les appeler les *Celtes*, comme on le fait si souvent.'[3] As to the eminent historian himself, I need hardly say that M. Martin adheres to the popular use of the word Kelt, and even goes so far as to speak of the county in which we are now assembled as 'le Glamorgan, le pays aujourdhui le plus celtique de l'Europe.'[4]

[1] The following are Broca's principal contributions to this vexed question:—'Qu'est-ce que les Celtes?' *Bulletins de la Société d'Anthropologie de Paris*, t. v. p. 457; 'Le Nom des Celtes,' *ibid.* 2 sér. t. ix. p. 662; 'Sur les Textes relatifs aux Celtes dans le Grande-Bretagne,' *ibid.* 2 sér. t. xii. p. 509; 'La Race Celtique, ancienne et moderne,' *Revue d'Anthropologie*, t. ii. p. 578; and 'Recherches sur l'Ethnologie de la France,' *Mém de la Soc. Anthrop.*, t. i. p. 1.

[2] *Bulletins de la Société d'Anthropologie de Paris*, 2 sér. t. xii. 1878, p. 511.

[3] *Ibid.* t. ix. 1874, p. 662.

[4] *Ibid.* t. xii. p. 486.

Whether we use the word Kelt in its wide linguistic sense or in the narrower sense to which it has been reduced by the French anthropologists, it is important to remember that the Welsh do not designate, and never have designated themselves by this term or by any similar word. Their national name is *Cymry*, the plural of *Cymro*. My former colleague, the Rev. Professor Silvan Evans, kindly informs me that the most probable derivation of this word is from *cyd-* (the *d* being changed to *m* for assimilation with the following *b*, like the *n* of its Latin cognate *con*) and *bro* , 'country,' the old form of which is *brog*, as found in *Allobrogæ*, and some other ancient names. The meaning of *Cymry* is therefore 'fellow-countrymen,' or compatriots. Such a meaning naturally suggests that the name must have been assumed in consequence of some foreign invasion—possibly when the Welsh were banded together against either the Romans or the English. If this assumption be correct it must be a word of comparatively late origin.

At the same time, the similarity between *Cymry* and *Cimbri*—the name of those dread foes of the Romans whom Marius eventually conquered—is so close as to naturally suggest a common origin for the two names, if not for the people who bore the names.[1] The warlike Cimbri have generally been identified with the people who inhabited the Cimbric peninsula, the *Chersonesus Cimbrica*, now called Jutland. Whether they were connected or not with the *Kimmerioi*, who dwelt in the valley of the Danube and in the Tauric Chersonesus, or *Crimea*, is a wider question with which we are not at the moment concerned. As to the ethnical relations of the Cimbri, two views have been current, the one regarding them as of Germanic, the other as of Keltic stock. Canon Rawlinson, in summing up the evidence on both sides, believes that the balance of opinion inclines to the Keltic view.[2] These Cimbri are described, however, as having been tall, blue-eyed, and yellow- or flaxen-haired men. Can we trace anything like these characters in the Cymry?

All the evidence which the ethnologist is able to glean from classical writers with respect to the physical characters and ethnical relations of the ancient inhabitants of this country, may be put into a nutshell, with room to spare. The exceeding meagreness of our data from this source will be admitted by anyone who glances over the passages relating to Britain which are collected in the *Monumenta Historica Britannica*. As to the people in the south, there is the well-known statement in Cæsar that the maritime parts of Britain, the southern parts which he personally visited, were peopled by those who had crossed over from the Belgæ, for what purpose we need not inquire. Of the Britons of the interior, whom he never saw, he merely repeats a popular tradition which represented them as aborigines.[3] They may, therefore, have been Keltic tribes, akin to the Celti of Gaul, though there is nothing in Cæsar's words to support such a view.

Tacitus, in writing the life of his father-in-law, Agricola, says that the Britons nearest to Gaul resembled the Gauls.[4] If he refers here to the sea-coast tribes in the south-east of Britain, the comparison must be with the Belgic and not with the Keltic Gauls. But his subsequent reference to the resemblance between the sacred rites of the Britons and those of the Gauls suggests that his remarks may be fairly extended to the inland tribes beyond the limits of the Belgic Britons, in which case the resembance may be rather with the Gaulish Kelts. Indeed, this inference, apart from the testimony of language, is the chief evidence upon which ethnologists have based their conclusion as to the Keltic origin of the Britons.

Our data for restoring the anthropological characteristics of the ancient Britons

[1] Prof. Rhys, however, has pointed out that there is no relation between the names. See *British Barrows*, by Canon Greenwell and Prof. Rolleston, 1877, p. 632.

[2] 'On the Ethnography of the Cimbri.' By Canon Rawlinson. *Journ. Anthrop. Inst.*, vol. vi. 1877, p. 150. See also Dr. Latham's paper, and postscript, 'On the Evidence of a Connection between the Cimbri and the Chersonesus Cimbrica,' published in his *Germania of Tacitus*.

[3] 'Britanniæ pars interior ab iis incolitur, quos natos in insula ipsi memoria proditum dicunt: maritima pars ab iis, qui prædæ ac belli inferendi causa ex Belgis transierant.'—*De Bello Gallico*, lib. v. c. 12.

[4] 'Proximi Gallis et similes sunt.'—*Agricola*, c. xi.

are but few and small. It is true that a description of Bunduica, or Boadicea, has been left to us by Xiphiline, of Trebizond; but then it will be objected that he did not write until the twelfth century. Yet it must be remembered that he merely abridged the works of Dion Cassius, the historian, who wrote a thousand years earlier, and consequently we have grounds for believing that what Xiphiline describes is simply a description taken from the lost books of an early historian who is supposed to have drawn his information from original sources. Now Boadicea is described in these terms: 'She was of the largest size, most terrible of aspect, most savage of countenance and harsh of voice, having a profusion of yellow hair which fell down to her hips.'[1] Making due allowance for rhetorical exaggeration, making allowance too for the fact that in consequence of her royal descent she is likely to have been above the average stature, and even admitting that she dyed her hair, it is yet clear that this British queen must be regarded as belonging to the xanthous type—tall and fair. The tribe of the Iceni, over which this blonde amazon ruled, is generally placed beyond the limits of the Belgic Britons; though some authorities have argued in favour of its Belgic origin. If the latter view be correct, we should expect the queen to be tall, light-haired, and blue-eyed; for, from what we know of the Belgæ, such were their features. Cæsar asserts that the majority of the Belgæ were derived from the Germans.[2] But notwithstanding this assertion, most ethnologists are inclined to ally them with the Celti, without, of course, denying a strong Teutonic admixture. Strabo says[3] that the Belgæ and Celti had the same Gaulish form, though both differed widely in physical characters from the Aquitanians. As to language, Cæsar's statement that the Belgic and Keltic differed, probably refers only to dialectical differences.[4] If a close ethnical relationship can be established between the Celti and the Belgæ, British ethnology clearly gains in simplification. To what extent the Belgic settlers in this country resembled the neighbouring British tribes must remain a moot point. According to Strabo,[5] the Britons were taller than the Celti, with hair less yellow, and they were slighter in build. By the French school of ethnologists the Belgæ are identified with the Cymry, and are described as a tall fair people, similar to the Cimbri already mentioned; and Dr. Prichard, the founder of English anthropology, was led long ago to describe the Keltic type in similar terms.[6]

Yet, as we pass across Britain westwards, and advance towards those parts which are reputed to be predominantly Keltic, the proportion of tall fair folk, speaking in general terms, diminishes, while the short and dark element in the population increases, until it probably attains its maximum somewhere in this district. As popular impressions are apt to lead us astray, let us turn for accuracy to the valuable mass of statistics collected in Dr. Beddoe's well-known paper 'On the Stature and Bulk of Man in the British Isles,'[7] a paper to which every student refers with unfailing confidence, and which will probably remain our standard authority until the labours of our own Anthropometric Committee are sufficiently matured for publication. Dr. Beddoe, summing up his observations on the physical characters of the Welsh as a whole, defines them as of 'short stature, with good weight, and a tendency to darkness of eyes, hair, and skin.' With regard to this tendency to darkness, it is well to look more searchingly at the district in which we are assembled. Dr. Beddoe, in another paper,[8] indicated the tendency by a numerical expression which he termed the *index of nigrescence*. 'In the coast-

[1] *Mon. Hist. Brit.*, Excerpta, p. lvi.

[2] 'Plerosque Belgas esse ortos ab Germanis.'—*De Bello Gall.* lib. ii. c. 4.

[3] Lib. iv. c. i.

[4] 'Quand César dit: *Hi omnes lingua, institutis, legibus, inter se differunt*, il faut traduire ici le mot *lingua* par *dialecte*.'—*Les Derniers Bretons.* Par Emile Souvestre, vol. i. p. 141.

[5] Lib. iv. c. 5.

[6] *Researches into the Physical History of Mankind.* By J. C. Prichard, M.D., F.R.S., vol. iii. p. 189.

[7] *Mem. Anthrop. Soc. Lond.* vol. iii. 1870, p. 384.

[8] 'On the Testimony of Local Phenomena in the West of England to the Permanence of Anthropological Types.'—*Ibid.* vol. ii. 1866, p. 37.

districts and low-lands of Monmouthshire and Glamorgan, the ancient seats of Saxon, Norman, and Flemish colonisation, I find,' says this observer, 'the indices of hair and eyes so low as 33·5 and 63; while in the interior, excluding the children of English and Irish immigrants, the figures rise to 57·3 and 109·5—this last ratio indicating a prevalence of dark eyes surpassing what I have met with in any other part of Britain' (p. 43).

Many years ago, Mr. Matthew Moggridge, whose scientific work is well known in this district, furnished the authors of the 'Crania Britannica' with notes of the physical characteristics of the Welsh of Glamorganshire. He defined the people as having 'eyes (long) bright, of dark or hazel colour, hair generally black, or a very dark brown, lank, generally late in turning grey.'[1]

There can be no question, then, as to the prevalence of melanism in this district. Nor does it seem possible to account for this tendency, as some anthropologists have suggested, by the influence of the surrounding media. Even those who believe most firmly in the potency of the environment will hardly be inclined to accept the opinion seriously entertained some years ago by the Rev. T. Price, that the black eyes of Glamorganshire are due to the prevalence of coal fires.[2] Long before coal came into use there was the same tendency to nigrescence among the Welsh. This may be seen, as Dr. Nicholas has pointed out, in the bardic names preserved in ancient Welsh records, where the cognomen of *du*, or 'black,' very frequently occurs. Thus, in the 'Myvyrian Archaiology of Wales,' between A.D. 1280 and 1330, there are registered four 'blacks' to one 'red' and one 'grey'—namely, Gwilym *Ddu*, Llywelyn *Ddu*, Goronwy *Ddu*, and Dafydd *Ddu*.[3]

The origin of this dark element in the Welsh is to be explained, as everyone will have anticipated, by reference to the famous passage in Tacitus, which has been worn threadbare by ethnologists. Tacitus tells us that the ancient British tribe of Silures—a tribe inhabiting what is now Glamorganshire, Monmouthshire, Herefordshire, and parts at least of Brecknockshire and Radnor—had a swarthy complexion, mostly with curly hair, and that from their situation opposite to Spain there was reason to believe that the Iberians has passed over the sea and gained possession of the country.[4] It will be observed that although Tacitus speaks of their dark complexion, he does not definitely state that the hair was dark; but this omission has, curiously enough, been supplied by Jornandes, a Goth who, in the sixth century, wrote a work which professes to be an extract from the lost history of Cassiodorus, wherein the very words of Tacitus are reproduced with the necessary addition.[5] With these passages before us, can we reasonably doubt that the swart blood in the Welsh of the present day is a direct legacy from their Silurian ancestors?

Setting what Tacitus here says about the Silures against what he says in the next sentence about the Britons nearest to Gaul (p. 5), it is clear that we must recognise a duality of type in the population of Southern Britain in his day. This fact has been clearly pointed out by Professor Huxley as one of the few 'fixed points in British ethnology.'[6] At the dawn of history in this country, eighteen centuries ago, the population was not homogeneous, but contained representatives both of Professor Huxley's *Melanochroi* and of his *Xanthochroi*. If we have any regard whatever

[1] *Cran. Brit.* vol. i. p. 53.

[2] *Essay on the Physiognomy and Physiology of the Present Inhabitants of Britain*, 1829.

[3] *The Pedigree of the English People*, fifth edition, 1878, p. 467.

[4] 'Silurum colorati vultus et torti plerumque crines, et posita contra Hispania, Iberos veteres trajecisse, easque sedes occupasse, fidem faciunt.'—*Agricola*, c. xi.

[5] 'Sylorum (= Silurum) colorati vultus, torto plerique crine, *et nigro* nascuntur.'—*De Rebus Geticis*, c. ii.; quoted in *Mon. Hist. Brit.*, Excerpta, p. lxxxiii. It is conjectured that the classical word *Silures* is derived from the British name *Essyllwyr*, the people of *Essyllwg*. See Nicholas's *History of Glamorganshire*, 1874, p. 1. It is difficult to determine how far and in what respects the Silures resembled, or differed from, the other inland tribes. Of the Caledonians and of the Belgæ we know something, but of the other inhabitants we are quite ignorant.

[6] *Critiques and Addresses*, p. 166.

for the persistence of anthropological types, we should hesitate to refer both of these to one and the same elementary stock. We are led, then, to ask, Which of these two types, if either, is to be regarded as Keltic?

It is because both of these types, in turn, have been called Keltic that so much confusion has been imported into ethnological nomenclature; hence the common-sense conclusion seems to be that neither type can strictly be termed Keltic, and that such a term had better be used only in linguistic anthropology.[1] The Kelt is merely a person who speaks a Keltic language, quite regardless of his race, though it necessarily follows that all persons who speak similar languages, if not actually of one blood, must have been, at some period of their history, in close social contact. In this sense, all the inhabitants of Britain, at the period of the Roman invasion, notwithstanding the distinction between Xanthochroi and Melanochroi, were probably to be styled Kelts. There can be little doubt that the xanthous Britons always spoke a Keltic tongue; but it is not so easy to decide what was the original speech of their melanochroic neighbours.

The existence of two types of population, dark and fair, side by side, is a phenomenon which was repeated in ancient Gaul. As the Silures were to Britain so were the Aquitani to Gaul—they were the dark Iberian element. Strabo states that while the natives of Keltic and Belgic Gaul resembled each other, the Aquitanians differed in their physical characters from both of these peoples, and resembled the Iberians. But Tacitus has left on record the opinion that the Silures also resembled the Iberians; hence the conclusion that the Silures and the Aquitanians were more or less alike. Now it is generally believed that the relics of the old Aquitanian population are still to be found lingering in the neighbourhood of the Pyrenees, being represented at the present day by the Basques. A popular notion has thus got abroad that the ancient Silures must have been remotely affined to the Basque populations of France and Spain. Nevertheless, the modern Basques are so mixed a race that, although retaining their ancient language, their physical characters have been so modified that we can hardly expect to find in them the features of the old Silurians. Thus, according to the Rev. Wentworth Webster, the average colour of the Basque hair at the present day is not darker than chestnut.[2]

Neither does language render us any aid towards solving the Basque problem. If the Silures were in this country prior to the advent of the Cymry, and if they were cognate with the Basques, it seems only reasonable to suppose that some spoor of their Iberian speech, however scant, might still be lingering amongst us. Yet philologists have sought in vain for the traces of any Euskarian element in the Cymraeg. Prince Louis Lucien Bonaparte, perhaps the only philologist in this country who has a right to speak with authority on such a subject, has obligingly informed me that he knows of no connexion whatever between the two languages. Still it must be remembered that the Iberian affinity of the Silures, suggested by the remark of Tacitus, does not necessarily mean Basque affinity. Some philologists have even denied that the Basques are Iberians.[3] All that we seek at present to establish is this—that the dark Britons, represented by the tribe of Silures, although they came to be a Keltic-speaking people, were distinct in race from the fair Britons, and therefore in all likelihood were originally distinct in speech. Nor should it be forgotten that relics of a pre-Keltic non-Aryan people have been detected in a few place-names in Wales. Thus, Professor Rhys is inclined to refer to this category such names as Menapia, Mona, and Mynwy[4]—the last-named being a place (Monmouth) within the territory of the old Silures, where we are now assembled. We may also look for light upon this subject from a

[1] An excellent argument against the employment of national names by anthropologists will be found in a paper by Mr. A. L. Lewis 'On the Evils arising from the use of Historical National Names as Scientific Terms.'—*Journ. Anthrop. Inst.* vol. viii. 1879, p. 825.

[2] 'The Basque and the Kelt.'—*Journ. Anthrop. Inst.* vol. v. 1. 76, p. 5.

[3] 'La Langue Iberienne et la Langue Basque.' Par M. Van Eys. *Revue de Linguistique.* July, 1874.

[4] 'Lectures on Welsh Philology,' 2nd ed., p. 181.

paper which will be laid before the Department by Mr. Hyde Clarke. On the whole it seems to me safer to follow Professor Rolleston in speaking of the dark pre-Keltic element as *Silurian* rather than as Basque or as Iberian.[1] ('British Barrows,' p. 630.)

There is, however, quite another quarter to which the anthropologist who is engaged in this investigation may turn with fair promise of reward. I need scarcely remind anyone in this department of the singularly suggestive paper which was written more than fifteen years ago by the late Dr. Thurnam, 'On the Two Principal Forms of Ancient British and Gaulish Skulls.'[2] The long-continued researches of this eminent archæological anatomist led him to the conclusion that the oldest sepulchres of this country—the chambered and other long barrows which he explored in Wilts and Gloucestershire—invariably contained the remains of a dolichocephalic people, who were of short stature, and apparently were unacquainted with the use of metals. The absence of metal would alone raise a suspicion that these elongated tumuli were older than the round, conoidal, or bell-shaped barrows, which contain objects of bronze, if not of iron, with or without weapons of stone, and commonly associated with the remains of a taller brachycephalic people.

Even before Dr. Thurnam forcibly pointed attention to this distinction, it had been independently observed by so experienced a barrow-opener as the late Mr. Bateman,[3] whose researches were conducted in quite another part of the country—the district of the ancient Cornavii. Moreover, Professor Daniel Wilson's studies in Scotland had led him to conclude that the earliest population of Britain were dolichocephalic, and possessed, in fact, a form of skull which, from its boat-like shape, he termed *kumbecephalic*.[4] Nor should it be forgotten that as far back as 1844 the late Sir W. R. Wilde expressed his belief that in Ireland the most ancient type of skull is a long skull, which he held to belong to a dark-complexioned people, probably aboriginal, who were succeeded by a fair, round-headed race.[5]

But while this succession of races was recognised by several observers, it remained for Dr. Thurnam to formulate the relation between the shape of the skull and that of the barrow in a neat aphorism which has become a standing dictum in anthropology—'Long barrows, long skulls: round barrows, round skulls; dolichotaphic barrows, dolichocephalic crania; brachytaphic barrows, brachycephalic crania.' No doubt exceptional cases may occur in which round skulls have been found in long barrows, but these have generally been explained as being due to secondary interments. On the other hand, the occasional presence of long skulls in round barrows presents no difficulty, since no one supposes that the early dolichocephali were exterminated by the brachycephali, and it is therefore probable that during the bronze-using period, when round tumuli were in general use, the two peoples may have dwelt side by side, the older race being, perhaps, in a state of subjugation.

It is not pretended that Thurnam's apophthegm has more than a local application. 'This axiom,' its author admitted, 'is evidently not applicable unless with considerable limitations, to France.' Although it is here called an 'axiom,' it is by no means a self-evident proposition, the relation between the shape of the skull and the shape of the burial-mound being purely arbitrary. The proposition which connects the two is simply the expression of the results of accumulated observations, and it is of course open to doubt whether the number of observations was sufficiently great to warrant the generalisation. But the only test of the validity of any induction lies in its verification when applied to fresh instances,

[1] W. von Humboldt in his famous essay, 'Prüfung der Untersuchungen über die Urbewohner Hispaniens vermittelst der Vaskischen Sprache,' does not admit, on philological evidence, any extension of the Iberians to this country. See c. 44: 'Ueber den Aufenthalt Iberischer Völkerschaften ausserhälb Iberien; in den von Celten bewohnten Ländern.'

[2] *Memoirs of the Anthrop. Soc. Lond.* vol. i. 1865, p. 120; vol. iii. 1870, p. 41.

[3] *Ten Years' Diggings*, 1861, p. 146.

[4] *Prehistoric Annals of Scotland*, 1851.

[5] *On the Ethnology of the Ancient Irish.*

and it is remarkable that when long barrows and chambered tumuli have since been opened in this country the evidence has tended in the main to confirm Dr. Thurnam's proposition.

It is commonly believed that the brachycephali of the round barrows came in contact with the dolichocephali as an invading, and ultimately as a conquering, race. Not only were they armed with superior weapons—superior in so far as a metal axe is a better weapon than a stone axe—but they were a taller and more powerful people. Thurnam's measurements of femora led to the conclusion that the average height of the brachycephali was 5 feet 8·4 inches, while that of the long-headed men was only 5 feet 5·4 inches.[1] Not only were they taller, but they were probably a fiercer and more warlike race. In the skulls from the round barrows the superciliary ridges are more prominent, the nasals diverge at a more abrupt angle, the cheek-bones are high, and the lower jaw projects, giving the face an aspect of ferocity, which contrasts unfavourably with the mild features of the earlier stone-using people.

On the whole, then, the researches of archæological anatomists tend to prove that this country was tenanted in ante-historic or pre-Roman times by two peoples who were ethnically distinct from each other. It is difficult to resist the temptation of applying this to the ethnogeny of Wales. Does it not seem probable that the early short race of long-skulled, mild-featured, stone-using people may have been the ancestors of the swarthy Silurians of Tacitus; while the later tall race of round-skulled, rugged-featured, bronze-using men may have represented the broad-headed, Keltic-speaking folk of history? At any rate, the evidence of craniology does not run counter to this hypothesis. For Dr. Beddoe's observations on head-forms in the West of England have shown that 'heads which are ordinarily called brachycephalic belonged for the most part to individuals with light hair,' while the short dark-haired people whom he examined were markedly dolichocephalic.[2] At the same time it must be admitted that his observations lend 'no support to the view that the Keltic skull has been or would be narrowed by an admixture of the Iberian type.' It should not, however, be forgotten that the same observer, in referring to a collection of crania from the Basque country preserved in Paris, says 'the form of M. Broca's Basque crania was very much that of some modern Silurian heads.'[3]

According to the view advocated by Thurnam we have a right to anticipate that the oldest skulls found in this country would be of dolichocephalous type; and such I believe to be actually the case. Dr. Barnard Davis, it is true, has stated in the *Crania Britannica* that the ancient British skull must be referred to the brachycephalic type; and such an induction was perfectly legitimate so long as the craniologist dealt only with skulls from the round barrows or from similar interments. But the long-barrow skulls examined by Professor Rolleston,[4] and the Cissbury skulls recently studied by the same anatomist,[5] are decidedly dolichocephalic, as also are all the early prehistoric skulls which have been found of late years in France. While referring to craniology in this country, I may perhaps be allowed to remark that the eminent Italian anthropologist, Dr. Paolo Mantegazza, in a suggestive paper which has just appeared in his valuable journal, the *Archivio per l'Antropologia*, has referred to the Englishman's contempt for craniological work—work but little worthy of the practical spirit of the Anglo-Saxon race.[6] No doubt it is desirable to increase the number of our observations, but still

[1] *Mem. Anthrop. Soc. Lond.* vol. iii. 1870, p. 73.

[2] *Ibid.* vol. ii. 1866, p. 350.

[3] *Ibid.* p. 356.

[4] 'On the People of the Long Barrow Period,' *Journ. Anthrop. Inst.*, vol. v. 1876, p. 120.

[5] *Ibid.* vol. vi. 1877, p. 20; vol. viii. 1879, p. 377.

[6] The whole passage so amusingly refers to the national idiosyncrasies of craniologists, that it is well worth reproduction. 'In Francia, Broca, il pontefice massimo dell' *ipercraniologia* moderna, col suo ardore eternamente giovanile, non studia più i crani, ma i cervelli; in Germania si prendono ancora misure sui teschi, ma con *rationabile obsequio*, quasi si dovesse adempiere ad un dovere noioso; in Inghilterra

the good-humoured remark about despising craniology can hardly be applied to a country which numbers among its living men of science such eminent craniologists as Professor Busk, Professor Cleland, Dr. Barnard Davis, and Professors Flower, Huxley, and Rolleston.

It may naturally be asked whether the researches of archæologists in Wales lend any support to Thurnam's hypothesis. Nothing, I conceive, would be easier than to show that very material support has come from this quarter; but I have abstained, of set purpose, from introducing into this address any remarks on the prehistoric archæology of Wales. For I have not forgotten that we are to have the privilege of hearing an evening lecture on 'Primeval Man' by so distinguished an archæologist and naturalist as Professor Boyd Dawkins. No one has done more in this country to forward Thurnam's views, whether by actual exploration or by writing, than Professor Dawkins; and if I have not referred to his work, especially to his discoveries in Denbighshire, it has been simply because I was anxious to avoid trespassing on any subject which he is likely to bring forward.[1]

Setting aside, then, any archæological evidence derived from the bone-caves, barrows, or other sepulchres in Wales, we may finally look at the outcome of our inquiry into Welsh ethnogeny. If we admit, as it seems to me we are bound to admit, the existence of two distinct ethnical elements in the Welsh population, one of which is short, dark, and dolichocephalic—call it Silurian, Atlantean, Iberian, Basque, or what you will; and the other of which is tall, fair, and brachycephalic, such as some term Cymric, and others Ligurian; then it follows that by the crossing of these two races we may obtain not only individuals of intermediate character, but occasionally more complex combinations; for example, an individual may have the short stature and long head of the one race, associated with the lighter hair of the other; or again, the tall stature of one may be found in association with the melanism and dolichocephalism of the other race. It is, therefore, no objection to the views herein expressed if we can point to a living Welshman who happens to be at once tall and dark, or to another who is short and fair.

At the same time, I am by no means disposed to admit that when we have recognised the union of the xanthous and melanic elements in Wales, with a predominance of the latter in the south, we have approached to anything like the exhausting limit of the subject. Still earlier races may have dwelt in the land, and have contributed something to the composition of the Welsh. In fact, the anthropologist may say of a Welshman, as a character in 'Cymbeline' says of Posthumus when doubtful about his pedigree,

'I cannot delve him to the root.'

It is possible that the roots of the Welsh may reach far down into some hidden primitive stock, older mayhap than the Neolithic ancestors of the Silurians; but of such pristine people we have no direct evidence. So far, however, as positive investigation has gone, we may safely conclude that the Welsh are the representatives, in large proportion, of a very ancient race or races; and that they are a composite people who may perhaps be best defined as *Siluro-Cymric*.

Many other questions relating to Welsh ethnology press for consideration—such as the hypothesis that the Kymro was preceded, in parts at least of Wales, by the Gael; but such questions must be dismissed from present discussion, for I fear that my remarks have already overrun the limits of a departmental address. Let us hope, however, that much light may be thrown upon a variety of questions bearing upon local anthropology in the course of the discussions which will arise in this department during the present session of the Association.

si continua a sprezzare la craniologia, come cosa poco degna dello spirito pratico della razza anglosassone; e in Italia, paese più scettico di tutti, perchè più antico e più stanco di tutti, si continua a misurare, pur sorridendo dell' improba e pur inutile fatica.'—*La Riforma Craniologica; Archivio*, vol. x. 1880, p. 117.

[1] For Prof. Boyd Dawkins' contributions to the subject see his interesting works on *Cave-hunting*, 1874, and on *Early Man in Britain*, 1880.

The following Papers were read :—

1. *Notes on the Origin of the Malagasy.* *By* C. STANILAND WAKE.

After referring to the traces of early Arab influence in Madagascar, the paper proceeded to show the close agreement in manners and customs between the Malagasy and the Siamese and other peoples of the Indo-Chinese peninsula. The Malagasy were then shown not to have any *special* connection, in either customs or physical characters, with the islanders of the Pacific, their agreement in certain particulars being due to their common origin in South-eastern Asia, a conclusion which is confirmed by the evidence of language. The author considered that the peculiarities presented by the Hovas and allied tribes, as distinguished from the other Malagasy, were due to the Arab element which was introduced into South-eastern Madagascar, perhaps indirectly, from the Indian Archipelago, about the eighth century, A.D. Traces of Hindu influence are also perceptible among the Malagasy, owing to intercourse with the Hindus before the migration from the Indian Archipelago. Whether these Asiatic settlers found an earlier race inhabiting Madagascar is doubtful; but some of the Malagasy tribes possess many features in common with various African peoples, which are probably due to their having had a common origin.

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2. *On the Antiquities of Loughor Castle.*[1] *By* B. JONES.

An ancient British camp or station, called 'Llwchdwr,' utilised by the Romans, and called 'Luecarum.' It had an outer and inner moat, and a watercourse from the river Llw, about five miles distant, to feed the moats, and the garrison was called 'Poundagwrdrwg.'

The remains of the ancient castle are situated on the eastern bank of the delta of the river Llwchdwr, a muddy stream commanding views of the valley and country all around—quite a 'bella vista.' An outpost called 'Stoutwall' existed, and a sudatorium, west of the church, taken away by the South Wales Railway. Roman tiles have been found in the sudatorium with a dog's footprint, also some pottery and Roman coins, some in possession of the writer. A foot-bridge crossed the river to the hospitium of the garrison, now called spitty.

The Via Julia came direct from Nedum, or Neath, to Luecarum. Traces of it existed until recently, passing Pen-lle-gaer as an intermediate camp, from which the Via Julia diverged northward to a bridge over the Loughor river at Llandilo-taly-bont, leading to a Roman camp at Estemenlle, on its way to the Roman 'Maridunum,' or Carmarthen. The ancient town of Loughor was situated south of the castle; traces of it still to be seen. The present town is built chiefly on the inner moat. There exists still a building called the 'sanctuary,' supposed to be the Roman garrison chapel; and Pentwyn Hill, inside the outer moat, was probably the garrison exercise-ground.

The Roman coins comprise some of Trajan, Nerva, and Antoninus, and several others in Mr. Jones's collection (some found at Loughor), also other more modern coins—some Saxon found in the ruins of the old Manor House in Temple Street, Swansea, and also coins found in a foundation of Christ's Hospital in London.

Mr. Jones has also a *Druid's bead*, found in a cairn on Cefenbryn Common in Gower. Mr. Jones mentions various other coins in his collection.

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3. *On Australian Autochthony.* *By* W. FORSTER.

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4. *On Drum-signalling in Africa.* *By* HYDE CLARKE.

This subject had been brought before the Association formerly by Captain Cameron, R.N., and Mr. Clarke proceeded to give some explanations, based on com-

[1] Published *in extenso* in the *Cambrian* of 3rd September, 1880.

munications of Mr. Gardiner, H.M. Service, West Coast of Africa. Mr. Clarke did not consider the signals to be as by dot and dash (· —), but as due to the notes representing a consonant and vowel, and suited to the syllables of the native languages. If a note conventionally represented a consonant, then the people would so understand it, and make the syllable, the consonant being accompanied by its well-known vowel; there would rarely be three notes. He considered the term drum-speaking might be used, for the people so understood the several drums, whether employed for signalling, fetish-drums, or for reciting praises of chiefs. The drummer was employed by the mail steamers to communicate with the shore, and messages could be sent two miles, and answers returned, and by relays they could be transmitted twenty miles. He referred to the drum as a very ancient institution, and as giving name to Cybele and drum-shaped mountains, and hence to its adoption in ancient and modern mythology.

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5. *On a Manuscript, perhaps Khita, discovered by Captain Gill in Western China. By* Hyde Clarke.

This manuscript was found by Captain W. Gill, R.E., in his late travels, at Kudeu, near Li-Kiang. Mr. Clarke had examined and found that the characters are allied to Khita (Hittite), Vei of W. Africa, Babylonian, Egyptian, and the ancient Shwo-wén of China, as well as to the Cypriote and Iberian alphabets, and notably the Runes. He had identified a considerable number of characters. He considered this as an outlying branch of the Khita class, and as attributable to the allied empire which gave the name of Kitai (Cathay) to the region. The whole was a testimony to the common distribution of ancient civilisation from one source throughout the world. The numerals were arranged partly like the Egyptian and partly like the Phœnician. ⸸ (or ÷) was repeatedly accompanied by a star ∗, and by the number seven in Egyptian order, IIII III, (4 and 3), like a group of seven pyramids in Egypt or Mexico. The mythological reference he considered to be the god Saba. 4 was IIII, 5 III II, 6 III III, 8 IIII IIII, 9 III III III. The MS. is possibly a copy of sculptured inscriptions. There may perhaps be cartouches in it. Besides characters, there are, as in Khita, animals and animals' heads in pairs (totems), and, besides, the fish.

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6. *Recent Doubts on Monosyllabism in Philological Classification. By* Hyde Clarke.

Mr. Hyde Clarke pointed out that his determination, supported by Dr. Carl Abel, &c., now showed that the Chinese, and Indo-Chinese, and Egyptian, and Coptic, are not in their origin monosyllabic, but contain dissyllabic roots of which the final vowel is elided. This rendered the term monosyllabic inapplicable for a class of languages, or for an epoch in their history. The formation of words in the Semitic languages was a simple handing down from the prehistoric period, an application of differentiation and of affixes, in comparison with which inflection is a minor characteristic. The doctrine of an Aryan primitive language and civilisation is a simple imagination, the Aryan languages being like the others—developed from the prehistoric epoch. No such thing as a single typical primeval language had ever existed; but, on the contrary, fifty primeval languages or more founded on the same system, but with various words.

FRIDAY, AUGUST 27.

The following Papers were read:—

1. *On the Stone Age in South Africa. By* W. D. Gooch, *C.E.*

The author discussed the subject from the following aspects:—

1. Types of Implements.
2. Distribution of Implements.
3. Character of Deposits in which they occur.
4. Character of material from which they are fashioned.

The ethnological facts suggested were

First, the presence of a primeval low stage of existence, correlating the usual earliest evidences of man upon earth, as found in other countries.

Its indications are found in the *quaternary* strata of Natal, and probably, on more complete examinations of South Africa, will be universally seen in deposits of similar age.

There seems reason to believe that the earliest beds in which anthropological traces occur are 'glacial.'

The *materials* used in the earlier strata are *Grit* and sandstone of a metamorphic character, with doubtful examples of indurated shale; these being gradually replaced in the latter strata by harder Trachyte, metamorphic rocks, and even Chalcedony. The *working of the materials is rude*, displaying a *very* limited power of fashioning either a constant shape or type, striving rather after a keen edge or point, as the 'summum bonum' to be achieved.

Rough clubs or celts of sandstone, with rude and irregular-shaped assegai weapons for thrusting or throwing, appear to have been the methods of *offence* at command.

For sewing skins together, thorns of plants and sinews of animals were ready to hand.

Pottery, which seems *doubtfully present*, is unburnt and unornamented.

This represents a 'Palæolithic Era' in South Africa.

Second. To the proceeding by intra-development, or grafted on it by a wave of development from the North, succeeded a period which is represented by the contents of the *upland strata* of Natal and the eastern province of the 'Old Colony.' This indicates a state in which the use of the *bow* was well known, and the javelin forms of the Celts were well-developed and formed by '*chipping*' of a coarse character.

The coarse and less effective materials, sandstone and grit, had been discarded, and the harder sorts of quartz, trachyte, metamorphic and chalcedonic rocks were used to provide flakes. These *Flakes* were keen, symmetrically fashioned, and of a general uniformity in shape and character, but *untrimmed*. *Pottery* had become well known, but its ornamentation and good burning had not yet been arrived at.

Most of the alluvial deposits of the uplands and the Æolian of the coasts yield relics of this period.

Third. Almost allied to the last-named, and found insensibly rising from it, especially in the Æolian strata of the *coast-lands* of Natal, is a period in which *polished stone*, and *ornamented* pottery, with wrought weapons in chalcedony of a '*trimmed*' character, are found associated with rougher implements in siliceous and other rocks. The arrow-heads are of a shape which suggests not only knowledge and *use of the bow*, but of *poison*. War clubs, consisting of perforated stones well-wrought and polished, belong to this age, and form a connecting link between this period, locally developed in Natal, and the next one.

The *fourth* period has a similar aspect to the third, except in its pottery. The materials used are of a highly *siliceous character*; the forms of all the weapons, whether picks, scrapers, or arrow-heads, are usually improved by *chipping* and *trimming* the original flake at the edges. The variety of types of form is very much increased, and many uses not clearly suggested by the weapons themselves

are now indicated. The arrow-head prevails, and assegai-heads of a light character, adapted for throwing, such as the 'Pondas,' 'Gaikas,' and 'Galekas' of to-day employ, preponderate. The small arrow-heads of chalcedony are very broad and often *minute*, and evidently were adapted to the use of poison to supplement their effect.

War-clubs are abundant, but no other form of *polished* weapon is found. Mullers and mortars for preparing roots, grain, and paints are seen, and the character of the life led seems to be identical with that now followed by the Korannas and other tribes allied to the Bosjesmen, inhabiting those districts in which relics of this age abound.

The *Pottery* of this *development is coarse* in shape, design, and manufacture, and very devoid of ornament. It is traceable from the highlands, Overberg, at the Diamond Fields southward till the Cape of Good Hope is reached; through the Overberg, Berg, and Cape districts, but is not found where the third period *is developed.*

The *fifth* and last period only differs from the preceding one in the perfection of the workmanship of the implements found in the Cape deposits. It presents the same aspect in pottery and types of weapons. The essentially *local* occurrence of this period only on the Cape Flats, points to a sudden improvement in the knowledge of working in stone, which seems only to be explained by the supposition of an ingraft of a race, which landing at Table or False Bays, there located their personal acquaintance with stone-fashioning, acquired among their own people in another clime.

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2. *On an Ancient Settlement found about* 21 *feet beneath the surface of the peat, in the coal-bog near Boho, county Fermanagh. By* Thomas Plunkett, *M.R.I.A.*

This interesting discovery consists of the remains of two log-huts found in a primitive crannoge 21 feet beneath the peat. The depression now filled with peat was a lake-basin at the period the island and log-huts were constructed. Shell-marl was found a few feet below the crannoge, also in various places in the bog where the peat had been cut to any great depth. The crannoge measured 10 by 14 yards. The more complete hut was 6½ feet wide and about 7½ long, inside measurement.

Its framework consisted of four massive posts of oak at the corners. An oak beam or thick bar passed through each pair of posts. Oak plank, about seven feet long, rested at each end on the beams and formed the floor of the hut. The sides of the structure were supported by large logs of oak piled on each other horizontally. Fragments of oak plank were found partly burnt; it is supposed the roof was destroyed by fire.

Flint implements, hand-made pottery, and other objects were found in connection with the huts, but no metal of any kind.

A large stump of pine was found *in situ* above the level of the floors of the huts, and had in its rootlets charcoal and kitchen-midden *débris*. The author is of opinion that the huts were formed before the age of bog pine, as no pine occurs below the level of the site on which the huts stood. The fact that 21 feet of dark compact peat had grown since the structures were formed is substantial evidence of their great antiquity.

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3. *On the Structure of Round Barrows. By* Professor G. Rolleston, *M.D., F.R.S.*

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4. *On the Structure of Long Barrows. By* Professor G. Rolleston, *M.D., F.R.S.*

5. *On Prehistoric Times in the Valley of the Rhine.* *By* Professor SCHAAFFHAUSEN.

The author described the results of his observations made in the Valley of the Rhine, between Mayence and Cologne. The burial-places of pre-Roman times are always situated on the ancient banks of this river. The immense prehistoric beds of our present rivers must be considered in close connection with the greater extension of the ice-hills in the mountains, which are the principal sources of the great rivers. It has lately been observed in the neighbourhood of Berlin, which is situated in the ancient bed of the Spree, that all remains of the stone and bronze periods are found in the higher land, whilst those of the iron period are found at a lower level.

Professor Schaaffhausen believed that Neanderthal man was living during the glacial period. There are found in Switzerland stakes, pointed by a human hand, in a formation, which is placed between two glacial periods. Near Coblenz, in the valley of the Moselle, was found, deep in the diluvial clay of the river, the skull of *bos moschatus*, a mammal, which lives now only in the coldest northern regions; the outside of this skull bears irrefutable marks of human stone implements; it is evident, therefore, that man was living during the glacial period of the Rhenish country.[1]

Professor Schaaffhausen also adduced evidence in proof of the existence of man at the time when the craters and large lava-streams near the Rhine were formed.

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6. *On the Original Neanderthal Skull.* *By* Professor SCHAAFFHAUSEN.

Professor Schaaffhausen expressed his conviction that this skull (which he exhibited) is not that of an idiot, nor is its peculiarity the result of disease, but it is a typical form, which represents the lowest degree of development of the human skull hitherto observed.

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7. *On a Palæolithic Stone Implement from Egypt.* *By* H. STOPES, *F.G.S.*

The author drew attention to the exceptional position and physical conditions of Egypt, making it probable that the greater number of the prehistoric implements of that country were covered with Nile mud, and consequently difficult to find. These he deemed sufficient reasons to account for the negative evidence of many authors not having at present been refuted by the discovery of palæolithic implements. Details were then given of the finding of a remarkably fine palæolith of the true river-drift type, at a distance of half a mile from the Spring of Moses, near Cairo, in latitude 30° 1′, longitude 31° 20′. It is of red porphoritic conglomerate, precisely similar to that found at Gebel Achmar, a few miles distant, and upon this fact the author laid considerable stress, as direct evidence that it was made and used in the neighbourhood in which it was picked up. The implement bears traces of considerable wear by blown sand. Its greatest length is 5·5 inches, width 3·8 inches, and thickness 1·5. It has the regular shape of river-drift palæoliths, although it is thinner and has a finer cutting point than those made of flint; the cutting edge is chipped and worn by use. It was lying exposed upon the surface, with its best side upwards, and seemed to be in an old dried-up river-bed. It resembles South African palæoliths in having two pieces knocked from its upper edge. The author then commented upon the value of the discovery in disproving the objections of Marriette, Brugsch, and others as to the existence of the Stone Age in Egypt.

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8. *On a Palæolithic Flint Implement from Palestine.* *By* H. STOPES, *F.G.S.*

The author described a flint implement of the river-drift type, found by him February 13, 1880, about two and a half miles from Jerusalem, on the road to Bethlehem. It was by the (so-called) road, lying with many thousands of rough flints

[1] *Cf.* meeting of the German Anthrop. Soc. at Strasburg, Aug. 1879.

of the common flint of Judæa. Its length is 4·4 inches, width 3·5 inches, and greatest thickness 1·4 inches. Either when being made or during use, it has lost a large splinter from its bottom edge, nearly to the centre, and has apparently been much used, as its cutting edge is much chipped and worn, and it has recently been chipped a number of times by being struck with the hoofs of passing horses and other animals.

SATURDAY, AUGUST 28.

The Department did not meet.

MONDAY, AUGUST 30.

The following Report and Papers were read:—

1. *Report of the Anthropometric Committee.*—See Reports, p. 120.

2. *On a Pocket Registrator for Anthropological Purposes.* *By* FRANCIS GALTON, *M.A.*, *F.R.S.*

The author exhibited a small instrument $\frac{1}{4}$ inch thick, 4 inches long and $1\frac{3}{4}$ wide, furnished with five stops, each communicating by a ratchet with a separate index arm that moves round its own dial-plate. The registrator may be grasped and held unseen in either hand with a separate finger over each stop. When any finger is pressed on the stop below it, the corresponding index arm moves forward one step. Guides are placed between the stops to ensure the fingers occupying their proper positions when the instrument is seized and used in the pocket, or when it is slipped inside a loose glove or other cover. It is possible by its means to take anthropological statistics of any kind among crowds of people without exciting observation, which it is otherwise exceedingly difficult to do. The statistics may be grouped under any number of headings not exceeding five. If it should ever be thought worth while to use a registrator in each hand, ten headings could be employed. The instrument that was exhibited worked well, but it was the first of its kind and might be improved. It was made by Mr. Hawkesley, surgical instrument maker, 300 Oxford Street, London. The author also drew attention to the ease with which registers may be kept by pricking holes in paper in different compartments with a fine needle. A great many holes may be pricked at haphazard close together, without their running into one another or otherwise making it difficult to count them afterwards. The mark is indelible, and any scrap of paper suffices. The needle ought to project a very short way out of its wooden holder, just enough to perforate the paper, but not more. It can then be freely used without pricking the fingers. This method, however, requires two hands, and its use excites nearly as much observation as that of a pencil.

3. *Additional Remarks on the Greek Profile* (*incorrectly so called*). *By* J. PARK HARRISON, *M.A.*

It was stated in a previous communication that the continuity of the forehead and nasal-bone in a straight line, which is so marked a peculiarity in early Greek statues and coins, is not found to exist either in ancient Greek skulls in our museums,

or in the effigies of kings and heroes after the date of Alexander the Great, when numismatists inform us that the natural features came to be represented in Greece. It was added, however, in the paper alluded to, that the feature in question was not to be considered, on this account, as merely ideal. Skulls from Palmyra and ancient Thebes show that people existed who partially possessed the peculiarity; and numerous sepulchral monuments, and terra cottas from Tyre and Aradus in the galleries of the Louvre as well as one from Sidon in the British Museum, which it can scarcely be doubted were intended to be likenesses, appear to point to the race subsequently called Phœnician as the one possessing the feature in question.

This identification has been since carried a step further. The effigies on the Carthaginian coins show unmistakably, in the African character of the lips, the mixture of blood in the Punico-Phœnician or Carthaginian race; and undoubtedly helps to prove that the straight line of forehead and nose, also observed in these coins, had its derivation from Tyre. The same prominent lips are also met with on some of the coins of Sicily; and the peculiarity exists amongst the Moors at the present day, who are believed to be a race composed of Carthaginians and Berbers, whose profile, in like manner, shows the same straight line as the Phœnicians.

In Egypt, an examination of the frescoes from its early tombs, so carefully copied in Rosellini's great work, shows that amongst the more cultivated ranks, especially the officials, the feature is continually met with. And Egyptologists inform us that the people who occupied the Delta, long before Phœnicians were known by that name, were much employed by the native dynasties, and it is probable navigated their sea-going ships, the native Egyptians having, it is well known, a dread of the sea themselves.

Certainly the feature in question is found to have been portrayed in Egypt long before it was represented in sculpture and in terra-cotta statuettes in Greece, and is even seen in the fresco of one of the gods of Egypt, copied by Rosellini (pl. lxvii).

Doubt has been felt whether any human cranium ever existed without a hollow or indent beneath the brow-ridge; but it is sufficient if an abnormal slope in the forehead co-exists with a straight nose; the muscles that stretch from the brow-ridge to the nasal arch would then complete the feature.

Exceptionally straight profiles, it should be mentioned, have been noticed in Attica, the coasts of Asia Minor, and some of the Greek islands. And there are two crania from ancient Athens, in the Museum of the Royal College of Surgeons that contrast strongly with a number from that locality, and other parts of Greece, in the same museum. It has been assumed, as in the case of the skulls from Thebes in Egypt, that these are Phœnician, since they have the heavy brow-ridges and slightly receding foreheads that appear to have been characteristic of the race. Consequently it may be that the people who have been noticed with the straight line of profile, as still existing, are descendants of Phœnician settlers. They are met with precisely where traces of that remarkable race might be found, and that even at Athens, where they occupied a quarter of their own.

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4. *On the British Flint-workers at Brandon. By* J. PARK HARRISON, *M.A.*

At the last meeting of the Association Mr. Skertchly expressed a strong belief that the Brandon Flint-works had been in continuous operation from neolithic times to our own day; the demand for 'strike-a-lights' alone, in all probability, keeping the art of flint-knapping in action, though flint implements for other purposes also, agricultural and domestic, may have been in requisition long after iron came into general use; more especially in the neighbourhood of factories. In the Orkneys, it is credibly reported that flint knives are still preferred to steel for paring apples.

As it appeared likely, if the art had been kept up in the manner supposed, that it would have been confined to certain families, and so have tended to perpetuate racial characteristics, a visit was made, soon after the Sheffield Meeting, to the locality of the works at Brandon, when it was at once apparent that the flint-knappers and their families, as well as a large portion of the general population of

the village, to a more or less extent, contrasted strongly in colour of hair and eyes with the people of Norfolk and Suffolk on the borders of which two counties Brandon is situated. Very dark hair and eyes evidently predominated, whilst they were almost wanting in the ranks of the militia and volunteers who were then in training, and so could be inspected for the purpose of testing this point. Of eighty recruits of the West Norfolk regiments, only three were entered in the register as having dark hair and eyes, and seventeen only with a depressed nasal-bone. Photographs of a number of the Brandon inhabitants have been obtained [shown], and several have been mistaken by persons acquainted with the Principality for Welsh; whilst others were thought by French anthropologists, to whom they were shown, to resemble the Iberian type of the Continent.

Though it has been supposed that the flint-works at Cissbury might also have continued in operation long after the Roman times, a greater mixture of races would appear to have occurred there, from causes peculiar to the locality, than in the more remote village of Brandon, where the march of civilisation was less rapid; consequently it is not believed that any of the original flint-workers of Cissbury have now any representatives existing; though here and there one may fancy that the type occasionally comes out through atavism. At Brandon there can scarcely be a doubt that we still possess examples of an early British race.

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5. *On the Retention of Ancient and Prehistoric Customs in the Pyrenees. By* Dr. PHENÉ, *F.S.A., F.R.G.S.*

The author pointed out that he had the honour at the last meeting, at Sheffield, to lay before this Section some matters which had come under his notice rather unexpectedly while he was making quite a different class of inquiries, to pursue which he had visited the Pyrenees. The particulars were crude and incomplete, but he felt it a duty to lay before this society the matter as far as he had it under his observation, that others might have an opportunity of examining it as well as himself, or, in the event of his being prevented, from any cause, investigating further, that it might not be lost to observation.

He said: 'I this year pursued the subject steadily, making photographs of the greater points of interest where roads permitted conveyance of the necessary apparatus, and I not only find my views confirmed, but also that several Frenchmen of science have been following the same investigations, so that I am able to add their testimony to my own.

'These gentlemen have very kindly placed the results of their investigations before me, and have expressed interest in my own researches.

'The discovery of a new field of Gallic monuments, with interments and cinerary urns of the oldest type, is not only interesting, but does not stand alone, as with these are found a class of monuments hitherto entirely overlooked by antiquaries, and also customs retained by the population of the surrounding districts of a nature so peculiar that, while they probably throw a light upon some past customs of these people not before known, they stand now in an almost unknown position.

'To make quite sure of my subject, I again approached the district through Languedoc, where there is a complete absence of even the most usual representations, either in sculpture or painting, of the serpent or dragon. Stopping at the ancient cathedral of St. Bertrand-de-Comminges, the old Roman station of Lugdunum Convenarum, the inquirer all at once finds himself in a different region, and as it were in a different age.

'Over the principal doorway at the west side, the Madonna and Child occupy a chair made of dragons exactly identical with the dragon chair occupied by King David I., of Scotland, as shown on his great seal. I produce the photograph and great seal. Within the church, so very unsymbolic has some one been, that a dried crocodile represents the veritable dragon the saint cleared out of the district.

'Such symbolism, apparently, runs in particular districts, and which are almost always marked by old stations of the Romans, and more lately of the Templars.

'These are all indicative of the serpent or dragon, from frescoes only three centuries old, to sculptures, mounds, or earthworks, and alignements of granite blocks—all being made to represent the serpent, counting as many thousand years. Mons. Julien Sacaze, writing of these stones, which are in the locality where he was born, says: "*les alignements sinueux étaient des symboles de la divinité*," and goes on to quote a number of native persons who admitted, when he interrogated them, that they worshipped them as such, notwithstanding their present religion; it was the belief of their ancestors they said. The most remarkable of these objects are three mounds, in the forms of serpents, which have been appropriated, one by a chamber of Roman construction, possibly as a security for wealth, one by a very ancient church, and the third, unmolested, has been lately found to contain a large deposition of Celtic incinerary urns, the place of deposition being almost about midway from the head to the tail. In the same position, in the mound on which is the church, were found a large number of Gallo-Romanic votive altars and other objects. Amongst those of this description in the neighbourhood, some altars dedicated to mountains were found, two peaks of the Maladetta being named, evidently showing that the occupation was in early Roman and Pagan times.

'On the crests and sides of the mountains, on both sides of the Pyrenees, *i.e.* in Spain and France, are found sepulchral arrangements of stones, somewhat different from any distinctly recorded amongst our antiquities. These consist of a number of circles adjoining each other; in the centre of each is a cist with an urn, having burnt bones, and the form of the circles is that of a wavy or serpentine cross.

'Mons. Gourdon gives a drawing of one on the Spanish side, and I have found several on the French side of the Pyrenees.

'I purchased the baker's bill, which I now produce, at Perpignan a few months ago, and though not so rustic as that of Brittany, it approaches more to our old Exhequer tally, and to the Welsh stick of writing, described in "Bardas," as well as to some elaborate and really wonderful calendars, still to be seen in the Cheetham Museum at Manchester, than to the rustic tally of Brittany. On crossing into Spain and prosecuting inquiries, I found the serpent or dragon emblem everywhere prominent, and even learned that the Tarasque, the ceremony of which is performed at Tarascon in Provence, was a well-known dragon with the Spanish people. On my explaining that I was making a study of the subject, I was told that though used as a popular diversion at fêtes, it had always a religious meaning, and that an old and well-known Spanish proverb ran thus—

"*No hay funcion sin Tarasque.*"
(No religious solemnity without the dragon.)

On the eve of Saint John, the whole Pyrenees being alive with the fires handed down from time immemorial as a custom, a vast pine, split into many vertical clefts, is raised at Luchon, and along the route I have described in the most secluded valleys, quite up to the Spanish frontier, as at the Valley du Lys, the pine has a cross of flowers on its summit, and being filled with combustible matter, burns in a brilliant column of fire.

'But at Luchon, in particular, living serpents are consumed in the flames. The priest, while he applies the torch, turns his face towards Spain and the Maladetta, or mountain of bad omen. The youths of the village have miniature cloven pines which they burn. I procured one with some little difficulty, which I produce; these they brandish while flaming, in serpentine curves, and cry loudly, "hilla-hilla!" (dead)—pronounced "*e*lla." Here we have apparently a corruption of the old classic cry of the Bacchanals, who, when lamenting the death of Bacchus, holding serpents in their hands, rushed about wildly crying, "Eva, eva!" These ceremonies are often prolonged into the night, and the wild cries are heard echoed from mountain to mountain. Mons. Sacaze states that this cry is an invocation of the Sun God. Be that as it may, it is the cry of the ancient Bacchanals, and is here accompanied, sometimes with real serpents, sometimes with simulated serpents of fire.

'The split pine was this year raised in my presence, on the back of the principal serpent mound in the valley I have mentioned, amidst the clanging of bells during

a service on Sunday. If there had been no other satisfaction to me in this, the evidence that this mound was artificially constructed, and not a natural formation, as shown by the cutting made into it, would have been great. The place where these cries are mostly practised has most remarkable sculptures of serpents, which I had photographed, and now produce.

'After the burning of the pine a rush is made by the more powerful and the burning embers carried off in their hands, regardless of pain. Pieces are then distributed to every household, and kept religiously during the year, as was the custom with the Ancient Britons.'

The author then illustrated, by diagrams, the course of the introduction of dragon worship into Europe.

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6. *On Anthropological Colour Phenomena in Belgium and elsewhere. By* J. BEDDOE, *M.D., F.R.S.*

In Germany, Switzerland, and Belgium, through governmental assistance, the colours of the eyes and hair of all the children in the primary schools have been observed and tabulated. The writer is very desirous that our own officials should lend similar assistance to the Anthropometric Committee of this Association. The results hitherto obtained have been of considerable importance, and those for Belgium are well shown in the monograph and maps of Professor Vanderkindere. These bring out a remarkable contrast between the Flemish and the Walloon provinces of Belgium, and tend strongly to prove the persistently hereditary character of even such physical characters as the colour of the hair and of the iris.

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7. *On the Pre-Cymric Epoch in Wales. By* HYDE CLARKE, *V.P.A.I.*

As existing materials for this epoch, the author enumerated river names, place names, record of the Silures, present ethnology, monuments, mythology, and folklore. He observed, as to river names, that a fundamental error was to regard all river names as Celtic, while as concerns the great rivers the names must belong to the preceding epoch. Such names as Thames and Shannon are to be found in the old and new world, and must consequently have been given by the pioneers of civilisation. Sabrina (the Severn) was illustrated by Siberis of Asia Minor, Sybaris and Tiberis of Italy, Iberus, Abarus, Hebrus, Khaboras. For the Tuerobis or Tivy of Wales, and the Ravius of Sligo Bay, parallels were also given. The root of Britannia and Sardinia, RDN, coincided with an extensive river series, Rhodanus, &c. He recommended the collection of all Welsh and Irish place-names, and their classified analysis. The Silures he regarded as belonging to the Iberians rather than to the Basques. To the early cultured population he assigned the Silures, the Veneti of Britanny, and possibly the Belgi. Verulanium, Camulodunum, Cunobulinus, &c., appeared to be Turanium names. He looked for survivals of ancient populations in Wales and Ireland, and recalled attention to the observations of Dr. Beddoe, F.R.S., as to obliquity of eyelid in South Wales. The discovery of Professor Rhys as to the god Nodent, &c. being Turanian and not Celtic, he supported. Mr. Clarke stated that the word Druid came from the same linguistic elements, and stated that their priesthood assimilated rather to the Egyptian, Brahmin, and Etruscan than to the Roman priesthood. The incidents of the mythology of Britain he considered to be of this class, and not Phœnician, which was itself of the common stock. The desirability of studying the folk-lore of Wales and the other Celtic countries, under this aspect, he pointed out, for many of the Welsh legends had been identified as members of the general folklore of antiquity.

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8. *On the Antiquity of Gesture and Sign Language, and the Origin of Characters and Speech.* By HYDE CLARKE, *V.P.A.I.*

The author, extending the observations of Colonel Mallery, U.S.A., gave examples of the connection of signs with characters, and showed that the same psychological relations in the representation of various ideas prevailed throughout, and that there was a general connection of signs, characters, and speech. There was no evidence of the priority of speech, but of the dependence of speech in its beginning on sign language as an illustration. It was indeed quite possible that some existing sculptured symbols may belong to an epoch anterior to speech. A sign language could be complete and copious in itself. He described what he had seen of the mutes of the seraglio at Constantinople, whom he considered to represent the ancient sign language of the eastern courts, and that recorded in classic writers. With regard to the sign language of the North American Indians, he supported Dr. E. B. Tylor in considering it to be of common and ancient origin. He said it was very desirable to have the sign language of the Pomo and Hidatsa Indians, who possibly represented, in language, the mound-builders.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *Surgery and Superstition in Neolithic Times.* By Miss A. W. BUCKLAND.

The object of this paper was to bring before the Anthropological Department of the British Association the frequent use of trepanning in neolithic times, as proved by the late Dr. Broca; to call attention to the proofs he has given of the facts, and to his explanation of the reason of the practice, and of the superstitions associated with it, as also its connexion with the use of cranial amulets.

1. Dr. Broca asserts in his work on the subject that in neolithic times a surgical operation was practised which consisted in making an opening in the skull, chiefly of infants, in order to cure certain internal maladies, and that these maladies were epilepsy and other convulsive disorders which in early times were confounded with epilepsy.

2. That such individuals as survived this operation were looked upon as endowed with peculiar properties of a mystic character and when they died rounds (*rondelles*) or fragments were frequently cut from the trepanned skull to serve as amulets, these amulets being cut by preference from the portion of the skull close to, and embracing, a part of the cicatrised hole caused by the trepan.

Dr. Broca proved by experiment that holes resembling those discovered could be scraped in a child's skull in five minutes, with a flint implement, whilst the operation would take an hour on an adult skull; he also shows conclusively that these holes could not have been the result of accident or disease. He believes that these trepanned skulls prove that the people of neolithic times had attained to a belief in spirits, and regarded epilepsy as a possession by spirits, the hole being cut to facilitate their expulsion, and he goes on to show that this belief descended to our own times; but, at the same time, he refers the whole of the trepanned skulls hitherto discovered to neolithic times, and thinks the custom died out with the introduction of bronze, and with it of a new religion and a new mode of sepulture. This conclusion the author of the paper doubts, because, as shown by Dr. Broca, the practice of trepanning for epilepsy, and by a very similar process to that of neolithic times, existed in France as late as the seventeenth century; and it was suggested that, although the practice of cremation may have destroyed the proofs in many cases,

that yet a more minute search would probably reveal traces of this curious custom, not only in France, but also in Great Britain and Ireland, and, in fact, wherever the holed stone is found as a covering to dolmens, believing that these holes are connected with the same superstition—being made to facilitate the entrance and exit of the spirit—and that the discovery of trepanned skulls in these dolmens would be of great ethnological importance, as proving, if not a racial identity, at least some communication between widespread peoples in prehistoric times. Looking upon it as an important fact that this custom of trepanning still exists, according to Dr. Broca, among some of the South Sea Islanders, the Kabyles of Algeria, and the mountaineers of Montenegro, Miss Buckland suggests that greater attention should be directed to this curious subject by English antiquaries.

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2. *On Bushmen Crania.* *By* Professor G. Rolleston, *M.D.*, *F.R.S.*

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3. *On the Salting Mounds of Essex.* *By* H. Stopes, *F.G.S.*

The author described the results of a series of investigations in these mounds. They consist of a reddish burnt clay, mixed freely with broken pottery of very rude type, charcoal, and wood-ashes, and clinkers. They exist only in one peculiar position. Out of very many examined, none were more than five feet above ordinary high-water mark, and none reached to low-water level. They are all uniform in character and composition, ranging from one to five feet in thickness, and possess the same character at top as at bottom. In size, they are very varied; some covering ten acres of ground. The number of them is unknown, but eighteen still exist between Strood and Virley (a space of about six miles). All occur in the marshes, but some are outside the sea-wall, and the greater number within it. Of those that are outside the existing sea-wall, two still retain the characteristic traces of Saxon tillage. Not a single mound is known to the author which faces the open sea. All of them fringe the creeks and estuaries, and they are invariably placed upon the London clay.

Many specimens of the pottery were exhibited, showing extremely coarse manufacture, all of which were imperfect. Two fragments were of Roman make. One flint scraper also was shown, but as it was upon the surface, the author considered it did not really belong to the mound upon which it was found.

Many local traditions were mentioned, and the opinions stated of several gentlemen as to their cause; notably that of the Rev. T. C. Atkinson, as to their being the resultants of salt-works of Roman date.

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4. *The Mountain Lapps.* *By* Lieutenant G. T. Temple, *R.N.*

The author stated that in Norway the Lapps are very generally, but incorrectly called Finns, and therefore often confounded with the real Finns or Quæns. They are regarded by most historians as the descendants of the aboriginal people of Norway. The total number of Lapps in Norway at the present time does not exceed 17,000, and of these upwards of 15,000 are sea or fisher Lapps, whose mode of life differs but little from that of the Norwegian fishermen. In the interior of Northern Norway, however, there are still about 1600 fjeld or mountain Lapps, who live partly by the chase and fresh-water fishing, but chiefly on the produce of their reindeer, the herds comprising in 1865 about 102,000 tame animals.

For centuries they have been in contact with civilisation, but to this day their mode of life is that of the half-wild hunter, the half-civilised nomad. Their usages, their ornaments, and their implements all bear traces of a wild state; and they are, alas! like the North American Indians, of all the allurements of civilisation, only susceptible to the temptation of spirits. It does not require very sharp

eyes to see that they are a doomed people, a people that will vanish from the earth, and at no very distant day be classed among the things that have been. Their physiognomy is decidedly Mongolian; and their physical constitution is very peculiar, as they unite great power of enduring fatigue and privation with extreme nervous sensibility. The Lapps of Norway are no longer heathens; they attend church, many can read, and all undergo some examination in the principles of religion before they are confirmed. They are fully alive to the importance of this, for no one can be married in Norway without producing a certificate of confirmation, and in spite of their roving habits, the Lapps are quite as much addicted to matrimony as we are ourselves.

The Lapps have now generally adopted the manners and customs, as well as the religion of their Norwegian or Russian neighbours; but on the banks of the Pasvig river there are some Greek-Catholic Lapps, who still go through the form of carrying off their brides from a hostile tribe.

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5. *The Hittites. By* W. St. C. Boscawen.

In this paper Mr. Boscawen gave an account of the discoveries which had been made by himself and others during the last year in the researches relating to the Hittites or North Syrian tribes.

The paper commences by pointing out the fact that the discovery and decipherment of the Egyptian and Assyrian inscriptions had resulted not only in restoring to us the history and geography, the literature and civilisation of their own country, but they had also shed great and important light on the condition of the surrounding nations. From the hieroglyphics and cuneiform inscriptions now accessible to us, it was possible to restore, with a great degree of accuracy, the political and ethnographical duration of that great and fertile middle state of Syria which divided the leading Asiatic and African powers. The details furnished by the inscriptions were also largely supplemented and illustrated by the panelled walls and sculptured slabs with which the Assyrians and Egyptians had decorated their palaces. The paper then proceeded to deal with the above authorities, from which it was shown that the whole of the district of North Syria was occupied by a powerful confederation of tribes, who were known to the Egyptians as the Kheta, and to the Assyrians as the Khattai. These were the Khittim or Hittites of the Hebrew writers. From the inscriptions information was deduced which showed that, although not to be regarded as a nation, this confederation of tribes formed an important factor in the political world of thirty years ago. Each alone was independent in its own district and capital city, but all were one and united when the invader threatened the land.

The author then sketched briefly the geographical position of the various tribes, showing their relationship to one another. The discovery of the site of the capital of the Khittai on the banks of the Euphrates had afforded a definite point and centre from which to commence the study of these tribes. The principal tribe of theKhittai proper was situated round about the city of Carchemish on the Euphrates. To the west of these were the Patanaians or the Padanaians, the tribe who occupied the plains to the north of Aleppo watered by the Koweik. The principal cities of these tribes were Khilbunu, the modern Aleppo, Arpad and Khazaz or Azaz. To the west of these tribes, in the plains of El Amk, were a number of small tribes who had come down from the slopes of the Taurus and Ammanus ranges, chief among whom were the Katai or Katu, a highly civilised tribe who occupied the shores of the Gulf of Antioch, and who were related to the Kitti or Kittim of Cyprus. South of these tribes, in the fertile valley of the Orontes and Litany rivers, were the tribes of the Routennu or Lutennu, who were almost independent of the Hittite league. Their chief cities were Kadesh on the Orontes, the capital and sacred city, and Hamath and Magiddo further south.

From an inscription of an early Babylonian king, Sargon I., King of Agane, the author showed that the Babylonians had, in the 17th century before the Christian era, come in contact with the Khittai or Hittites. Sargon I. carried at least

three campaigns into the Hittite country, one of which passed beyond the mainland and into the adjacent island of Cyprus. The effect of this contact with Babylon was shown in an interesting fragment preserved by the Hebrew writer of the book of Genesis which related to the purchase of the cave-sepulchre of Machpelah by the Hebrew patriarch. Here we find that the Babylonian commercial system, which was known certainly to Abraham, a native of Ur, was also known to Ephron the Hittite. Reference was next made to the hieroglyphic inscriptions recording the campaigns of Thothmes III., against the Rutennu. The composition of the southern confederation of tribes was explained, and their relationship to the Hittites proper explained. The defeat of the Rutennu or southern branch had opened up the way for the enlargement of the Hittite power, and the result was that in the time of Rameses II., the Greek Sesostris, we find most of the pre-Hellenic nations of Asia Minor who were the allies of the Hittites flocking to aid in repelling the invader.

Mr. Boscawen next proceeded to describe the ruins of the Hittite city of Carchemish, which he visited in the early part of the present year, and where he made drawings and copies of the sculptures and inscriptions. After describing the principal topographical features of the site, Mr. Boscawen proceeded to describe the sculptures discovered.

Basing his remarks on a sculpture representing the patron goddess of Carchemish, the Hittite Anatha or Anat—the Asiatic goddess, Mr. Boscawen proceeded to show how the introduction of the cult of this goddess in Asia Minor was due to the Hittites, who were shown by the monuments to have possessed all the principal characteristics of this pre-Hellenic cult as established at Ephesus.

Mr. Boscawen next showed how that the peculiar hierarchy of the Ephesian Artemis, with its high priest, 'the king bee,' and its priestesses, 'the bees,' was of Hittite origin. By means of this and the monuments, Mr. Boscawen showed the close relationship between the Hittites and the Assyrians, Teucrians, Dardanians, and other races of Asia Minor, and traced, by various monuments, the route by which the Hittites penetrated to the Ægean Sea.

A description was given of the other Hittite monuments from Carchemish, and also from Boghaz, Keui, and Eyuk, in Galatia.

The paper concluded with a description of the Hittite hieroglyphic syllabary, and special reference was made to a bilingual text which had recently been discovered.

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6. *On the Discovery of a Bi-lingual Seal in Cuneiform and Khita. By* HYDE CLARKE, *V.P.A.I.*

The author communicated the determination and discovery of the interpretation and language of the Khita (Hamath, Hittite, or Carchemish) inscriptions:—

Dr. Mordtmann found a bi-lingual seal, with the name of King Tarkondimotos in Cuneiform, and Professor Sayce has discovered that the other character is Khita. On this I have sent some observations.

Finding an impresion of the seal was in the British Museum, on Saturday, 28th August, I saw it there in company with Dr. Birch and Mr. Pinches, and I had already prepared a sketch which should give me, 1st, a form for king; 2nd, for head; 3rd, for children.

The seal is most beautifully engraved, but the forms are conventional, and therefore only to be defined by comparison with other types.

I found a head in character 2, and the two lines for son in character 3.

The head is that of an animal, and the first character is that of an animal. What specific animals these are I cannot yet absolutely determine for want of material. [They appear to be those of the Bull, which signifies Tura, and Lion which signifies Kun, which are found on the gold coins of Sardis in Lydia, and which are the gold pieces referred to in Ezra and Nehemiah as Adarkon and Darkomonim.]

The fourth character must be that for the title of king.

The bottom character is Land, as suggested by Mr. Boscawen.

The large side character must be Zume or Rume.

On leaving Dr. Birch and entering into the Museum I looked at the Carchemish sculptures, and there I found almost a replica of the seal, and other parallels, to which I called Dr. Birch's attention.

This Carchemish parallel of mine throws the most remarkable light on the seal.

It may be premised that my Carchemish inscription does not read from top to bottom, as we conceived from the Hamath the character does, but from left to right, while both the seal inscriptions are from right to left.

The animals are in the same order at Carchemish, apparently the secondary first, and the male or determinative second, as should be the case according to the comparative grammar I applied.

Thus, instead of King Tarkondimotos being simply a king of Cilicia, as proposed by Dr. Mordtmann, he must have been recognised on the site of the other monuments.

Another Carchemish parallel gives the female head, the kingly emblem, and the Zumei character, but is accompanied by a female emblem.

On careful comparison of the seal-inscription I differ from Professor Sayce. I find no determinative for God, and doubt if 'Land' is a determinative, but consider it to be a substantial word.

In my Carchemish parallel there is, however, a determinative · | ·, the very one I fixed upon years ago in my first establishment of the Khita character from the transcripts, which Capt. Burton thought to be registers of camel-marks. This male determinative is over the male or horned head, and I am not sure there is not a female determinative over the other head.

I must now communicate some further investigations, to enable the Section to understand the bearing of the facts before them. I was surprised to see a beast's head where I had expected to find the symbol of a man's head; but I saw that this head and the two heads figured in Carchemish sculpture, and in Capt. Gill's West China MSS., with this remarkable peculiarity, that the hair or beard under the chin of the beast is marked with three strokes.

I know that 3 is a sign for plural and collective, and 3 hairs represents many hairs.

There are also three strokes on each of the two copies of the kingly emblem and the seal, which may imply Great King.

I know that in the languages that I have assigned for the comparative philology of Khita, Tara and Kun figure for king, but as all such roots have several meanings, it struck me on reflection that the words might also mean animals.

On examination, I found that all the ancient words for king (and those now used in Africa) figure also in the names for animals, and afterwards that the names for God (and so far as I know Fetish) so figure. These are facts in perfect conformity with anthropological knowledge.

The animal, in our inscriptions represented by his head or mask, is the totem or fetish of the man—in this case of the king.

Why there should be two is, it may be presumed, to have a fortunate pair, a male and female, and for the same reason the inscription on the seal is double for the right and left hand of the king. On the earliest coins two animals were found.

Applying our anthropological knowledge we obtain a direct totem and fetish explanation from the 'Khita' mythology for that adopted from the ancients by the Greeks. This explains to us the animal metamorphoses of the gods, heroes, and kings, their animal emblems and animal sacrifices. The result of this will be a final rejection of the scheme of Sanscritic weather mythology for the explanation of more ancient anthropological facts.

Besides our gain on that head, we now know absolutely the linguistic nature of the Khita languages in Canaan, in Lydia, and in Etruria, whatever dialectic differences may have existed. The words Tar, ku or kun, and timme (dimi) are clear. The latter is child, son, offspring.

It is separable, we see, at Carchemish, so that the name became Tarkun, like the Etruscan Tarquin.

The names, continued as heroic names and popular names by the Greeks, still consisted of the lion, horse, wolf, &c., with the like termination, Damas.

[The emblems on the coins of Lydia, &c., are found to correspond with Lydian words of the same sound as the names of the cities.]

We are further in a condition to provide for Khita comparative philology and comparative grammar from living types on the lines so long laid down by me.

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7. *Further Researches on the Prehistoric Relations of the Babylonian, Chinese, and Egyptian Characters, Language, and Culture, and their Connection with Sign and Gesture Language. By* HYDE CLARKE, *V.P.A.I.*

This was in continuation of a paper on Chinese and other characters, read at the British Association Dublin Meeting (Journal, 1878, p. 590). The writer repeated that the characters and languages were of common origin, but of independent development; and the mythology also. The Chinese, Egyptian, Coptic, and Babylonian were not truly monosyllabic; but most of the assumed monosyllables are dissyllables. He exhibited illustrations of two series of Chinese characters, the Tau or + series, and the Round, O, converted into square. The + in Chinese, differentiated, represents 10, scholar or literate, earth, son, shield, market, door, rich, finger-nail, bull, and cow. He showed that all these differentiated cross-signs, representing apparently dissimilar ideas, are represented by words of an allied type in the corresponding languages. In dealing with the Round series, he gave similar illustrations for the signs sun, moon, face, ring, pot, enclosed ground or field, and their secondaries, woman, mother, blood, and also the numerals, four and two. In this series the Akkad or Babylonian characters conform, and, to some extent, Egyptian and Mexican. Mr. Clarke then passed to the Akkad phonetics, and these he showed were illustrated by the corresponding languages, so that the phonetics in Babylonia and China must have been invented by the pre-Akkad races, before the development of the Babylonian, and were not invented in Babylonia. The characters and the languages he connected with sign or gesture language. Extending the illustrations by Col. Mallery, U.S.A., of the relations of the signs of the North American Indians with Egyptian characters, Mr. Clarke gave further illustrations, and showed that there were a common psychological relation of the pre-historic languages and characters with the signs and gestures. Thus the languages and characters were founded on the signs and not the reverse. He exhibited from the signs the community of features between the signs and the languages. In reference to the population which had propagated early culture throughout the world, he still maintained that it was a white race, which had been seated in the highland and lake regions of Africa, and the migrations of which explain the early history of Egypt, of Western Asia, and Europe, and the other regions of the world.

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8. *On the 'Vei Syllabary' of Liberia, West Africa. By* HYDE CLARKE, *V.P.A.I.*

This syllabary had been discovered about 1849, by Lieut. Forbes, R.N., and chronicled by Rev. Dr. Koelle. The latter had been informed that it was invented by one Doala Bakere, and it was regarded as a unique example of such invention in those days. Mr. Clarke pointed out that it was not an alphabet, modelled on the neighbouring English, Arabic, or even Barber, but was a syllabary on the ancient model. The characters, sometimes ideographs, were not casual, but the exact reproduction of Khita (Hittite), West China, ancient Shwo-wen Chinese, and Babylonian, with occasional Egyptian, Libyan, Tamashek, and Berber, Cypriote, and Iberian. It was also occasionally written from top to bottom like Khita, &c. ·|· [÷] was employed alone and in combination, and also other well-known types. He therefore did not doubt that the Vei represented an ancient syllabary, and that it would be most valuable for the illustration of Khita and other ancient characters.

He repeated his observation that the Iberian was of common origin with the other ancient characters. Mr. Clarke referred to a Vei legend of Lake Zontori, to which on the conquest of the country the aboriginal king and his warriors had retired, and where their souls still dwell, and their songs are still heard. This is the parallel of the legend of Lake Fucinus, in Italy, and it had also Lydian connexions, while Veii was in Etruria on one side of Rome, and Fucinus on the other. Attaching to a lake Fuguene in New Granada was an allied legend. He showed that the Vei incidentally supported the Turanian origin maintained by him for the Runes and northern mythology and culture.

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9. *Note on a Chilian Tumulus. By* JOHN HALLAM MADGE.

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10. *India the Home of Gunpowder, on Philological Evidence. By* Dr. GUSTAV OPPERT.

DEPARTMENT OF ANATOMY AND PHYSIOLOGY.

CHAIRMAN OF THE DEPARTMENT—F. M. BALFOUR, M.A., F.R.S. (Vice-President of the Section).

THURSDAY, AUGUST 26.

The Department did not meet.

FRIDAY, AUGUST 27.

The CHAIRMAN delivered the following Address:—

IN the spring of the present year, Professor Huxley delivered an address at the Royal Institution, to which he gave the felicitous title of 'The Coming of Age of the Origin of Species.' It is, as he pointed out, twenty-one years since Mr. Darwin's great work was published, and the present occasion is an appropriate one to review the effect which it has had on the progress of biological knowledge.

There is, I may venture to say, no department of biology the growth of which has not been profoundly influenced by the Darwinian theory. When Messrs. Darwin and Wallace first enunciated their views to the scientific world, the facts they brought forward seemed to many naturalists insufficient to substantiate their far-reaching conclusions. Since that time an overwhelming mass of evidence has, however, been rapidly accumulating in their favour. Facts which at first appeared to be opposed to their theories have one by one been shown to afford striking proofs of their truth. There are at the present time but few naturalists who do not accept in the main the Darwinian theory, and even some of those who reject many of Darwin's explanations still accept the fundamental position that all animals are descended from a common stock.

To attempt in the brief time which I have at my disposal to trace the influence of the Darwinian theory on all the branches of anatomy and physiology would be

wholly impossible, and I shall confine myself to an attempt to do so for a small section only. There is perhaps no department of Biology which has been so revolutionised, if I may use the term, by the theory of animal evolution, as that of Development or Embryology. The reason of this is not far to seek. According to the Darwinian theory, the present order of the organic world has been caused by the action of two laws, known as the laws of heredity and of variation. The law of heredity is familiarly exemplified by the well-known fact that offspring resemble their parents. Not only, however, do the offspring belong to the same species as their parents, but they inherit the individual peculiarities of their parents. It is on this that the breeders of cattle depend, and it is a fact of every-day experience amongst ourselves. A further point with reference to heredity to which I must call your attention is the fact that the characters, which display themselves at some special period in the life of the parent, are acquired by the offspring at a corresponding period. Thus, in many birds the males have a special plumage in the adult state. The male offspring is not, however, born with the adult plumage, but only acquires it when it becomes adult.

The law of variation is in a certain sense opposed to the law of heredity. It asserts that the resemblance which offspring bear to their parents is never exact. The contradiction between the two laws is only apparent. All variations and modifications in an organism are directly or indirectly due to its environments; that is to say, they are either produced by some direct influence acting upon the organism itself, or by some more subtle and mysterious action on its parents; and the law of heredity really asserts that the offspring and parent would resemble each other if their environments were the same. Since, however, this is never the case, the offspring always differ to some extent from the parents. Now, according to the law of heredity, every acquired variation tends to be inherited, so that, by a summation of small changes, the animals may come to differ from their parent stock to an indefinite extent.

We are now in a position to follow out the consequences of these two laws in their bearing on development. Their application will best be made apparent by taking a concrete example. Let us suppose a spot on the surface of some very simple organism to become, at a certain period of life, pigmented, and therefore to be especially sensitive to light. In the offspring of this form, the pigment-spot will reappear at a corresponding period; and there will therefore be a period in the life of the offspring during which there is no pigment-spot, and a second period in which there is one. If a naturalist were to study the life-history, or, in other words, the embryology of this form, the fact about the pigment-spot would come to his notice, and he would be justified, from the laws of heredity, in concluding that the species was descended from an ancestor without a pigment-spot, because a pigment-spot was absent in the young. Now, we may suppose the transparent layer of skin above the pigment-spot to become thickened, so as gradually to form a kind of lens, capable of throwing an image of external objects on the pigment-spot. In this way a rudimentary eye might be evolved out of the pigment-spot. A naturalist studying the embryology of the form with this eye would find that the pigment-spot was formed before the lens, and he would be justified in concluding, by the same process of reasoning as before, that the ancestors of the form he was studying first acquired a pigment-spot and then a lens. We may picture to ourselves a series of steps by which the simple eye, the origin of which I have traced, might become more complicated; and it is easy to see how an embryologist studying the actual development of this complicated eye would be able to unravel the process of its evolution.

The general nature of the methods of reasoning employed by embryologists, who accept the Darwinian theory, is exemplified by the instance just given. If this method is a legitimate one, and there is no reason to doubt it, we ought to find that animals, in the course of their development, pass through a series of stages, in each of which they resemble one of their remote ancestors; but it is to be remembered that, in accordance with the law of variation, there is a continual tendency to change, and that the longer this tendency acts the greater will be the total effect. Owing to this tendency, we should not expect to find a perfect resemblance

between an animal, at different stages of its growth, and its ancestors; and the remoter the ancestors, the less close ought the resemblance to be. In spite, however, of this limitation, it may be laid down as one of the consequences of the law of inheritance that every animal ought, in the course of its individual development, to repeat with more or less fidelity the history of its ancestral evolution.

A direct verification of this proposition is scarcely possible. There is ample ground for concluding that the forms from which existing animals are descended have in most instances perished; and although there is no reason why they should not have been preserved in a fossil state, yet, owing to the imperfection of the geological record, palæontology is not so often of service as might have been hoped.

While for the reasons just stated, it is not generally possible to prove by direct observation that existing forms in their embryonic state repeat the characters of their ancestors, there is another method by which the truth of this proposition can be approximately verified.

A comparison of recent and fossil forms shows that there are actually living at the present day representatives of a considerable proportion of the groups which have in previous times existed on the globe, and there are therefore forms allied to the ancestors of those living at the present day, though not actually the same species. If therefore it can be shown that the embryos of existing forms pass through stages in which they have the characters of more primitive groups, a sufficient proof of our proposition will have been given.

That such is often the case is a well-known fact, and was even known before the publication of Darwin's works. Von Baer, the greatest embryologist of the century, who died at an advanced age but a few years ago, discussed the proposition at considerable length in a work published between the years 1830 and 1840. He came to the conclusion that the embryos of higher forms never actually resemble lower forms, but only the embryos of lower forms; and he further maintained that such resemblances did not hold at all, or only to a very small extent, beyond the limits of the larger groups. Thus he believed that, though the embryos of Vertebrates might agree amongst themselves, there was no resemblance between them and the embryos of any invertebrate group. We now know that these limitations of Von Baer do not hold good, but it is to be remembered that the meaning *now* attached by embryologists to such resemblances was quite unknown to him.

These preliminary remarks will, I trust, be sufficient to demonstrate how completely modern embryological reasoning is dependent on the two laws of inheritance and variation, which constitute the keystones of the Darwinian theory.

Before the appearance of the 'Origin of Species' many very valuable embryological investigations were made, but the facts discovered were to their authors merely so many ultimate facts, which admitted of being classified, but could not be explained. No explanation could be offered of why it is that animals, instead of developing in a simple and straightforward way, undergo in the course of their growth a series of complicated changes, during which they often acquire organs which have no function, and which, after remaining visible for a short time, disappear without leaving a trace.

No explanation, for instance, could be offered of why it is that a frog in the course of its growth has a stage in which it breathes like a fish, and then why it is like a newt with a long tail, which gradually becomes absorbed, and finally disappears. To the Darwinian the explanation of such facts is obvious. The stage when the tadpole breathes by gills is a repetition of the stage when the ancestors of the frog had not advanced in the scale of development beyond a fish, while the newt-like stage implies that the ancestors of the frog were at one time organised very much like the newts of to-day. The explanation of such facts has opened out to the embryologist quite a new series of problems. These problems may be divided into two main groups, technically known as those of phylogeny and those of organogeny. The problems of phylogeny deal with the genealogy of the animal kingdom. A complete genealogy would form what is known as a natural classification. To attempt to form such a classification has long been the aim of a large number of naturalists, and it has frequently been attempted without the aid of embryology. The statements made in the earlier part of my address clearly show how great an

assistance embryology is capable of giving in phylogeny; and as a matter of fact embryology has been during the last few years very widely employed in all phylogenetic questions, and the results which have been arrived at have in many cases been very striking. To deal with these results in detail would lead me into too technical a department of my subject; but I may point out that amongst the more striking of the results obtained *entirely* by embryological methods is the demonstration that the Vertebrata are not, as was nearly universally believed by older naturalists, separated by a wide gulf from the Invertebrata, but that there is a group of animals, known as the Ascidians, formerly united with the Invertebrata, which is now universally placed in the same class with the Vertebrata.

The discoveries recently made in organogeny, or the genesis of organs, have been quite as striking, and in many respects even more interesting, than those in phylogeny, and I propose devoting the remainder of my address to a history of results which have been arrived at with reference to the origin of the nervous system.

To render clear the nature of these results I must say a few words as to the structure of the animal body. The body is always built of certain pieces of protoplasm, which are technically known to biologists as cells. The simplest organisms are composed either of a single piece of this kind, or of several similar pieces loosely aggregated together. Each of these pieces or cells is capable of digesting and assimilating food, and of respiring; it can execute movements, and is sensitive to external stimuli, and can reproduce itself. All the functions of higher animals can, in fact, be carried on in this single cell. Such lowly organised forms are known to naturalists as the Protozoa. All other animals are also composed of cells, but these cells are no longer complete organisms in themselves. They exhibit a division of labour: some carrying on the work of digestion; some, which we call nerve-cells, receiving and conducting stimuli; some, which we call muscle-cells, altering their form—in fact, contracting in one direction—under the action of the stimuli brought to them by the nerve-cells. In most cases a number of cells with the same function are united together, and thus constitute a tissue. Thus the cells which carry on the work of digestion form a lining membrane to a tube or sac, and constitute a tissue known as a secretory epithelium. The whole of the animals with bodies composed of definite tissues of this kind are known as the Metazoa.

A considerable number of early developmental processes are common to the whole of the Metazoa.

In the first place every Metazoon commences its existence as a simple cell, in the sense above defined; this cell is known as the ovum. The first developmental process which takes place consists in the division or segmentation of the single cell into a number of smaller cells. The cells then arrange themselves into two groups or layers known to embryologists as the *primary germinal layers*. These two layers are usually placed one within the other round a central cavity. The inner of the two is called the hypoblast, the outer the epiblast. The existence of these two layers in the embryos of vertebrated animals was made out early in the present century by Pander, and his observations were greatly extended by Von Baer and Remak. But it was supposed that these layers were confined to vertebrated animals. In the year 1849, and at greater length in 1859, Huxley demonstrated that the bodies of all the polype tribe or Cœlenterata—that is to say of the group to which the common polype, the jelly-fish, and the sea-anemone belong—were composed of two layers of cells, and stated that in his opinion these two layers were homologous with the epiblast and hypoblast of vertebrate embryos. This very brilliant discovery came before its time. It fell upon barren ground, and for a long time bore no fruit. In the year 1866 a young Russian naturalist named Kowalevsky began to study by special histological methods the development of a number of invertebrated forms of animals, and discovered that at an early stage of development the bodies of all these animals were divided into germinal layers like those in vertebrates. Biologists were not long in recognising the importance of these discoveries, and they formed the basis of two remarkable essays, one by our own countryman, Professor Lankester, and the other by a distinguished German naturalist, Professor Haeckel, of Jena.

In these essays the attempt was made to show that the stage in development already spoken of, in which the cells are arranged in the form of two layers enclosing a central cavity has an ancestral meaning, and that it is to be interpreted to signify that all the Metazoa are descended from an ancestor which had a more or less oval form, with a central digestive cavity provided with a single opening, serving both for the introduction of food and for the ejection of indigestible substances. The body of this ancestor was supposed to have been a double-walled sac formed of an inner layer, the hypoblast, lining the digestive cavity, and an outer layer, the epiblast. To this form Haeckel gave the name of gastræa or gastrula.

There is every reason to think that Lankester and Haeckel were quite justified in concluding that a form more or less like that just described was the ancestor of the Metazoa; but the further speculations contained in their essays as to the origin of this form from the Protozoa can only be regarded as suggestive feelers, which, however, have been of great importance in stimulating and directing embryological research. It is, moreover, very doubtful whether there are to be found in the developmental histories of most animals any traces of this gastræa ancestor, other than the fact of their passing through a stage in which the cells are divided into two germinal layers.

The key to the nature of the two germinal layers is to be found in Huxley's comparison between them, and the two layers in the fresh-water polype and the sea-anemone. The epiblast is the primitive skin, and the hypoblast is the primitive epithelial wall of the alimentary tract.

In the whole of the polype group, or Cœlenterata, the body remains through life composed of the two layers, which Huxley recognised as homologous with the epiblast and hypoblast of the Vertebrata; but in all the higher Metazoa a third germinal layer, known as the mesoblast, early makes its appearance between the two primary layers. The mesoblast originates as a differentiation of one or of both the primary germinal layers; but although the different views which have been held as to its mode of origin form an important section of the history of recent embryological investigations, I must for the moment confine myself to saying that from this layer there take their origin—the whole of the muscular system, of the vascular system, and of that connective-tissue system which forms the internal skeleton, tendons, and other parts.

We have seen that the epiblast represents the skin or epidermis of the simple sac-like ancestor common to all the Metazoa. In all the higher Metazoa it gives rise, as might be expected, to the epidermis, but it gives rise at the same time to a number of other organs; and, in accordance with the principles laid down in the earlier part of my address, it is to be concluded that *the organs so derived have been formed as differentiations of the primitive epidermis.* One of the most interesting of recent embryological discoveries is the fact that the nervous system is, in all but a very few doubtful cases, derived from the epiblast. This fact was made out for vertebrate animals by the great embryologist Von Baer; and the Russian naturalist Kowalevsky, to whose researches I have already alluded, showed that this was true for a large number of invertebrate animals. The derivation of the nervous system from the epiblast has since been made out for a sufficient number of forms satisfactorily to establish the generalisation that it is all but universally derived from the epiblast.

In any animal in which there is no distinct nervous system, it is obvious that the general surface of the body must be sensitive to the action of its surroundings, or to what are technically called stimuli. We know experimentally that this is so in the case of the Protozoa, and of some very simple Metazoa, such as the fresh-water Polype or Hydra. The skin or epidermis of the ancestor of the Metazoa was no doubt similarly sensitive; and the fact of the nervous system being derived from the epiblast implies that the functions of the central nervous system, which were originally taken by the whole skin, became gradually concentrated in a special part of the skin which was step by step removed from the surface, and finally became a well-defined organ in the interior of the body.

What were the steps by which this remarkable process took place? How has it come about that there are nerves passing from the central nervous system to all parts of the skin, and also to the muscles? How have the arrangements for reflex actions arisen by which stimuli received on the surface of the body are carried to the central part of the nervous system, and are thence transmitted to the appropriate muscles, and cause them to contract? All these questions require to be answered before we can be said to possess a satisfactory knowledge of the origin of the nervous system. As yet, however, the knowledge of these points derived from embryology is imperfect, although there is every hope that further investigation will render it less so? Fortunately, however, a study of comparative anatomy, especially that of the Cœlenterata, fills up some of the gaps left from our study of embryology.

From embryology we learn that the ganglion-cells of the central part of the nervous system are originally derived from the simple undifferentiated epithelial cells of the surface of the body. We further learn that the nerves are out-growths of the central nervous system. It was supposed till quite recently that the nerves in Vertebrates were derived from parts of the middle germinal layer or mesoblast, and that they only became secondarily connected with the central nervous system. This is now known not to be the case, but the nerves are formed as processes growing out from the central part of the nervous system.

Another important fact shown by embryology is that the central nervous system, and percipient portion of the organs of special sense, are often formed from the same part of the primitive epidermis. Thus, in ourselves and in other vertebrate animals the sensitive part of the eye, known as the retina, is formed from two lateral lobes of the front part of the primitive brain. The crystalline lens and cornea of the eye are, however, subsequently formed from the skin.

The same is true for the peculiar compound eyes of crabs or Crustacea. The most important part of the central nervous system of these animals is the supracœsophageal ganglia, often known as the brain, and these are formed in the embryo from two thickened patches of the skin at the front end of the body. These thickened patches become gradually detached from the surface, remaining covered over by a layer of skin. They then constitute the supracœsophageal ganglia; but they form not only the ganglia, but also the rhabdons or retinal elements of the eye—the parts in fact which correspond to the rods and cones in our own retina. The layer of epidermis or skin which lies immediately above the supracœsophageal ganglia becomes gradually converted into the refractive media of the crustacean eye. A cuticle which lies on its surface forms the peculiar facets on the surface of the eye, which are known as the corneal lenses, while the cells of the epidermis give rise to lens-like bodies known as the crystalline cones.

It would be easy to quote further instances of the same kind, but I trust that the two which I have given will be sufficient to show the kind of relation which often exists between the organs of special sense, especially those of vision, and the central nervous system. It might have been anticipated *à priori* that organs of special sense would only appear in animals provided with a well-developed central nervous system. This, however, is not the case. Special cells, with long delicate hairs, which are undoubtedly highly sensitive structures, are present in animals in which as yet nothing has been found which could be called a central nervous system; and there is every reason to think that the organs of special sense originated *pari passu* with the central nervous system. It is probable that in the simplest organisms the whole body is sensitive to light, but that with the appearance of pigment-cells in certain parts of the body, the sensitiveness to light became localised to the areas where the pigment-cells were present. Since, however, it was necessary that stimuli received in such areas should be communicated to other parts of the body, some of the epidermic cells in the neighbourhood of the pigment-spots, which were at first only sensitive in the same manner as other cells of the epidermis, became gradually differentiated into special nerve-cells. As to the details of this differentiation, embryology does not as yet throw any great light; but from the study of comparative anatomy there are grounds for thinking that it was somewhat as follows:—Cells placed on the surface sent protoplasmic

processes of a nervous nature inwards, which came into connection with nervous processes from similar cells placed in other parts of the body. The cells with such processes then became removed from the surface, forming a deeper layer of the epidermis below the sensitive cells of the organ of vision. With these cells they remained connected by protoplasmic filaments, and thus they came to form a thickening of the epidermis underneath the organ of vision, the cells of which received their stimuli from those of the organ of vision, and transmitted the stimuli so received to other parts of the body. Such a thickening would obviously be the rudiment of a central nervous system, and it is easy to see by what steps it might become gradually larger and more important, and might gradually travel inwards, remaining connected with the sense organ at the surface by protoplasmic filaments, which would then constitute nerves. The rudimentary eye would at first merely consist of cells sensitive to light; at a later period there would be formed optical structures constituting the lens, which would throw an image of external objects upon it, and so convert the whole structure into a true organ of vision. It has thus come about that, in the development of the individual, the retina or sensitive part of the eye is first formed in connection with the central nervous system, while the lenses of the eye are independently evolved from the epidermis at a later period.

The general features of the origin of the nervous system which have so far been made out by means of the study of embryology are the following:—

(1) That the nervous system of the higher Metazoa has been developed in the course of a long series of generations by a gradual process of differentiation of parts of the epidermis.

(2) That part of the central nervous system of many forms arose as a local collection of nerve-cells in the epidermis, in the neighbourhood of rudimentary organs of vision.

(3) That ganglion cells have been evolved from simple epithelial cells of the epidermis.

(4) That the primitive nerves were outgrowths of the original ganglion cells; and that the nerves of the higher forms are formed as outgrowths of the central nervous system.

The points on which embryology has not yet thrown a satisfactory light are:—

(1) The steps by which the protoplasmic processes, from the primitive epidermic cells, became united together so as to form a network of nerve-fibres, placing the various parts of the body in nervous communication.

(2) The process by which nerves became connected with muscles, so that a stimulus received by a nerve-cell could be communicated to and cause a contraction in a muscle.

Recent investigations on the anatomy of the Cœlenterata, especially of jelly-fish and sea-anemones, have thrown some light on these points, although there is left much that is still obscure.

In our own country Mr. Romanes has conducted some interesting physiological experiments on these forms; and Professor Schäfer has made some important histological investigations upon them. In Germany a series of valuable researches have also been made on this group by Professors Kleinenberg, Claus and Eimer, and more especially by the brothers Hertwig, of Jena. Careful histological investigations, especially those of the last-named authors, have made us acquainted with the forms of some very primitive types of nervous system. In the common sea-anemones there are, for instance, no organs of special sense, and no definite central nervous system. There are, however, scattered throughout the skin, and also throughout the lining of the digestive tract, a number of specially modified epithelial cells, which are no doubt delicate organs of sense. They are provided at their free extremity with a long hair, and are prolonged on their inner side into a fine process which penetrates the deeper part of the epithelial layer of the skin or digestive wall. They eventually join a fine network of protoplasmic fibres which forms a special layer immediately within the epithelium. The fibres of this network are no doubt essentially nervous. In addition to fibres there are, moreover, present in the network cells of the same character as the multipolar ganglion-cells in

the nervous system of Vertebrates, and some of these cells are characterised by sending a process into the superjacent epithelium. Such cells are obviously epithelial cells in the act of becoming nerve-cells; and it is probable that the nerve-cells are, in fact, sense-cells which have travelled inwards and lost their epithelial character.

There is every reason to think that the network just described is not only continuous with the sense-cells in the epithelium, but that it is also continuous with epithelial cells which are provided with muscular prolongations. The nervous system thus consists of a network of protoplasmic fibres, continuous on the one hand with sense-cells in the epithelium, and on the other with muscular cells. The nervous network is generally distributed both beneath the epithelium of the skin and that of the digestive tract, but is especially concentrated in the disc-like region between the mouth and tentacles. The above observations have thrown a very clear light on the characters of the nervous system at an early stage of its evolution, but they leave unanswered the questions (1) how the nervous network first arose, and (2) how its fibres became continuous with muscles. It is probable that the nervous network took its origin from processes of the sense-cells. The processes of the different cells probably first met and then fused together, and, becoming more arborescent, finally gave rise to a complicated network.

The connection between this network and the muscular cells also probably took place by a process of contact and fusion.

Epithelial cells with muscular processes were discovered by Kleinenberg before epithelial cells with nervous processes were known, and he suggested that the epithelial part of such cells was a sense-organ, and that the connecting part between this and the contractile processes was a rudimentary nerve. This ingenious theory explained completely the fact of nerves being continuous with muscles; but on the further discoveries being made which I have just described, it became obvious that this theory would have to be abandoned, and that some other explanation would have to be given of the continuity between nerves and muscles. The hypothetical explanation just offered is that of fusion.

It seems very probable that many of the epithelial cells were originally provided with processes the protoplasm of which, like the protoplasm of the Protozoa, carried on the functions of nerves and muscles at the same time, and that these processes united amongst themselves into a network. By a process of differentiation parts of this network may have become specially contractile, and other parts may have lost their contractility and become solely nervous. In this way the connection between nerves and muscles might be explained, and this hypothesis fits in very well with the condition of the neuro-muscular system as we find it in the Cœlenterata.

The nervous system of the higher Metazoa appears then to have originated from a differentiation of some of the superficial epithelial cells of the body, though it is possible that some parts of the system may have been formed by a differentiation of the alimentary epithelium. The cells of the epithelium were most likely at the same time contractile and sensory, and the differentiation of the nervous system may very probably have commenced, in the first instance, from a specialisation in the function of part of a network formed of neuro-muscular prolongations of epithelial cells. A simultaneous differentiation of other parts of the network into muscular fibres may have led to the continuity at present obtaining between nerves and muscles.

Local differentiations of the nervous network, which was no doubt distributed over the whole body, took place on the formation of organs of special sense, and such differentiations gave rise to the formation of a central nervous system. The central nervous system was at first continuous with the epidermis, but became separated from it and travelled inwards. Ganglion-cells took their origin from sensory epithelial cells, provided with prolongations, continuous with the nervous network. Such epithelial cells gradually lost their epithelial character, and finally became completely detached from the epidermis.

Nerves, such as we find them in the higher types, originated from special differentiations of the nervous network, radiating from the parts of the central nervous system.

Such, briefly, is the present state of our knowledge as to the genesis of the

nervous system. I ought not, however, to leave this subject without saying a few words as to the hypothetical views which the distinguished evolutionist Mr. Herbert Spencer has put forward on this subject in his work on Psychology.

For Herbert Spencer nerves have originated, not as processes of epithelial cells, but from the passage of motion along the lines of least resistance. The nerves would seem, according to this view, to have been formed in any tissue from the continuous passage of nervous impulses through it. 'A wave of molecular disturbance,' he says, 'passing along a tract of mingled colloids closely allied in composition, and isomerically transforming the molecules of one of them, will be apt at the same time to form some new molecules of the same type,' and thus a nerve becomes established.

A nervous centre is formed, according to Herbert Spencer, at the point in the colloid in which nerves are generated, where a single nervous wave breaks up, and its parts diverge along various lines of least resistance. At such points some of the nerve-colloid will remain in an amorphous state, and as the wave of molecular motion will there be checked, it will tend to cause decompositions amongst the unarranged molecules. The decompositions must, he says, cause 'additional molecular motion to be disengaged; so that along the outgoing lines there will be discharged an augmented wave. Thus there will arise at this point something having the character of a ganglion corpuscle.'

These hypotheses of Herbert Spencer, which have been widely adopted in this country, are, it appears to me, not borne out by the discoveries to which I have called your attention to-day. The discovery that nerves have been developed from processes of epithelial cells, gives a very different conception of their genesis to that of Herbert Spencer, which makes them originate from the passage of nervous impulses through a tract of mingled colloids; while the demonstration that ganglion-cells arose as epithelial cells of special sense, which have travelled inwards from the surface, admits still less of a reconciliation with Herbert Spencer's view on the same subject.

Although the present state of our knowledge on the genesis of the nervous system is a great advance on that of a few years ago, there is still much remaining to be done to make it complete.

The subject is well worth the attention of the morphologist, the physiologist, or even of the psychologist, and we must not remain satisfied by filling up the gaps in our knowledge by such hypotheses as I have been compelled to frame. New methods of research will probably be required to grapple with the problems that are still unsolved; but when we look back and survey what has been done in the past, there can be no reason for mistrusting our advance in the future.

The following Papers were read:—

1. *On the Alkaline Fermentation of Urine. By* A. S. Lea.

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2. *On the Origin of the Head-Kidney. By* A. Sedgwick, *B.A.*

The hypothesis of Gegenbaur and Fürbringer as to the relation of the head-kidney to the hinder part of the excretory system was considered, the objections to it pointed out, and the following hypothesis put forward. The head-kidney is the anterior part of a primitive excretory organ possessed by some ancestral vertebrate, the posterior part of which has persisted as the Wolffian body. In support of this view it was pointed out that the structure of the head-kidney essentially resembles that of the Wolffian body. It was further noticed that, though at first sight the development of these two organs is entirely different, on a closer examination they are found to present a development fundamentally similar. The development of the Wolffian body in Amphibia and other animals with a head-kidney must be con-

sidered as very much modified and in no way representing the phylogenetic history; while that in Elasmobranchii, in which there is no head-kidney, may be looked upon as much more primitive.

Comparing the development of the Wolffian body in Elasmobranchii with that of the head-kidney in Amphibia, the fundamental similarity between them is at once apparent.

SATURDAY, AUGUST 28.

The Department did not meet.

MONDAY, AUGUST 30.

The Department did not meet.

TUESDAY, AUGUST 31.

The following Report was read:—

Report of the Committee for investigating the Influence of Bodily Exercise on the Elimination of Nitrogen.—See Reports, p. 159.

Section E.—GEOGRAPHY.

President of the Section—Lieut.-General Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.

THURSDAY, AUGUST 26.

The President delivered the following Address:—

My recent predecessors in this chair have dealt, with a knowledge and ability with which I cannot vie, not only with great problems in terrestrial physics, such as the genesis of our oceans, continents, and mountain-chains; the circulation of the waters of the ocean, with its consequences on climate; the reciprocal influence of conditions of nature upon man, and of man's ability to modify those conditions; but also on the progress of geographical discovery on the great theatres of political interest or commercial rivalry; and the archæology of our science, as regards Asia, has been touched by a master's hand. Turning, then, from themes on which I could offer nothing worthy of your attention, I find, with a sense of relief, that there is a region of the globe, and it is one with which I have the most personal acquaintance, which has received very little attention at their hands. I refer to the great continent of America, and more especially its northern portion; and I hope for your indulgence if I enlarge a little upon that theme.

How vast have been, in very recent times, the additions to our knowledge in that quarter, how continuous is the progress of discovery, cannot, I think, but worthily occupy your attention for a few minutes. In other regions Geography is the pioneer of Civilisation and Commerce. We look, and often look long, for their footsteps to follow. Here for the first time she has been outstripped, for the telegraph and the railway have tracked the forest or prairie, and traversed the mountains by paths before unknown to her.

I remember that patriarch of science, Sir Edward Sabine, once telling me how eagerly he, as a young man, had desired to retread the footsteps of Lewis and Clarke, whose journey from St. Louis to the Pacific in 1805, was at the time, and must long remain, one of the most remarkable achievements on record.

Let me, then, remind you that within living memory (I grant, a long one) no traveller known to fame had crossed the American continent from east to west, except Alexander Mackenzie, in 1793. No traveller had reached the American Polar Sea by land, except the same illustrious explorer and Samuel Hearne. The British Admiralty had not long before instructed Captain Vancouver to search on the coast of the Pacific for some near communication with a river flowing into or out of the Lake of the Woods. The fabulous Straits of Annian are to be found on maps of the last century. 'The sacred fires of Montezuma' were still burning in secluded valleys of Upper California when her Majesty ascended the throne.

It is very interesting to observe that De la Hontan, whose name has been recently given by the American geologists to the basin of the great Miocene Sea, now represented by Carson Lake in Nevada, ascended the Mississippi, and even penetrated up the Yellowstone, very nearly to the 'National Park,' at all events into the present territory of Montana, so early as 1687. He introduces into his

rude map a head-water lake, on Indian information, which must, I think, be identical with a lake in that reserve. 'Je sçais,' says his biographer, 'que tous les voyageurs sont sujets à caution, et que s'ils ne sont point parvenus au privilége des poëtes et des peintres, il ne s'en faut guère: mais il faut excepter de la noblesse; est il croyable qu'un baron voulut en imposer?' But I am not pursuing the attractive theme offered by historical geography, and must not dwell on the memorable expeditions of Franklin and Richardson, of Back and Simpson and Rae, but proceed to point out the many agencies at work of late years to open up the continent: the military operations, for example, of the United States' Government against Mexico; the discovery of the precious metals; the explorations for the Union Pacific and Canada Pacific Railways; International Boundary Surveys; the geological surveys of the American and Canadian Governments. These have all resulted in a surprising extension of geographical knowledge, without any of them having it particularly in view. It was a bold figure of speech of Lord Dufferin's which described the Rocky Mountains in 1877 as being nearly 'as full of theodolites as they could hold,' but the Dominion Government has spent about three-quarters of a million sterling on explorations or surveys for their railway, and we have only to glance at a recent map to discover nine sovereign states, and seven territories, west of the Mississippi, bounded by right lines, which neither war nor diplomacy has determined, laid out like garden-plots, to see that neither Asia nor Africa have unfolded more of their secrets in our times, than has the nobler continent where Britain has cast her swarms.

The thoroughness characteristic of the scientific operations of the American Government has been greatly favoured by the physical features of the region of their trigonometrical survey, in the American Cordilleras. Sharp rocky peaks, bare of vegetation, rise to altitudes of 10,000 to 12,000 feet, at convenient distances of 60 to 80 miles apart, so situated as to form well-conditioned triangles, while the purity of the atmosphere makes observation easy. In this manner has an immense region comprising some 87,000 square miles in Nevada, Utah, and Colorado, been topographically surveyed since 1867; not indeed with the detail of a European national survey, but with all the accuracy required for first settlement. The two prehistoric seas, now designated Lake Bonneville, of which Salt Lake is the remains, and Lake La Hontan, already referred to, have been defined, and facts of remarkable physical interest have been ascertained. The evaporation of Great Salt Lake, for example, is no longer in excess of its annual tribute; it has risen 11 feet since 1866. The natural basin of Pyramid Lake is now full, its level has risen 9 feet, and the overflow is filling up Winnemucca Lake in like manner; the latter lake has risen 22 feet, and its area has doubled within the same short period. We cannot allow the geologists to monopolise the interest of these physical changes, which the magnificent volume of Mr. Clarence King has presented to them.

Lying a little to the east and south of the region just referred to is another, which includes yet loftier mountains, and has been surveyed by Professor Hayden. Here, on the tributaries of the rivers Colorado and S. Juan, we find those mysterious monuments of an extinct civilisation and a dying people, the cliff-houses on the Rio Mancos and Rio de Chelly, the Pueblos of the Chaso Cañon; and here the wandering Apaches still practise on their prisoners those revolting and indescribable cruelties which make humanity shudder, and which seal their doom of extermination. No less than eighteen summits in the Sierra Blanca have been found to rise above 14,000 feet. Blanca Peak, in South Colorado, attains 14,464 feet, and is the monarch of mountains, if such there may be, in the great Republic. Lake Tahoe, the largest of western lakes, familiar to readers of the brilliant pages of Miss Bird, was surveyed by Lieutenant Macomb in 1877, and the height of Pyramid Peak ascertained to be 10,003 feet. A town of 20,000 inhabitants (Leadville, Colo.) has sprung into being at an elevation of 11,000 feet, which ranks it among the highest inhabited places on the globe.

Very different in their character are the survey operations of the Canadian Government in the north-west, where the problem presented is to prepare a vast territory, wholly wanting in conspicuous points, for being laid out in townships of

uniform area, and farms of uniform acreage. The law requires that the eastern and western boundaries of every township be true astronomical meridians; and that the sphericity of the earth's figure be duly allowed for, so that the northern boundary must be less in measurement than the southern. All lines are required to be gone over twice with chains of unequal length, and the land surveyors are checked by astronomical determinations. In carrying out this operation, which will be seen to be one of great nicety, five principal meridians have been rigorously determined, and in part traced—the 97th, 102nd, 106th, 110th, and 114th; and fourteen base-lines, connecting them, have been measured and marked. One of these, on the parallel of 52° 10′, is 183 miles long. Eleven astronomical stations have been fixed since 1876, and from these sixty-six determinate points have been fixed in latitude, forty-five in longitude, often under conditions of no little difficulty from the severity of the climate. The claims of Messrs. Alexander and Lindsay Russell, of Mr. Aldous, and Mr. King, the observers, to rank as scientific travellers, will, I am sure, be warmly recognised by this Section.

The sources of the Frazer river were first reached in February 1875, and found in a semicircular basin, completely closed in by glaciers and high bare peaks, at an elevation of 5300 feet. The hardy discoverer, Mr. E. W. Jarvis, travelled in the course of that exploration 900 miles on snow-shoes, much of it with the thermometer below the temperature of freezing mercury, and lived for the last three days, as he expresses it, 'on the anticipation of a meal at the journey's end.'

We are still imperfectly acquainted with the region north of the parallel of 50° in British Columbia, where the Canadian engineers have long been searching for a practicable railway line from one or other of three known passes of the Rocky Mountains proper, through the tremendous gorges of the Cascade Mountains, to the Pacific. These passes are, the Yellowhead, at an elevation of 3645 feet, the Pine river, at 2800 feet, and the Peace river, said to be only 1650 feet above the sea, all of them comparing very favourably in respect to height with the other trans-continental railways. The Union Pacific Railway, for example, runs, as you will remember, for 1500 miles at elevations of over 4500 feet, and its summit level is 8242 feet. The Dominion Government has recently adopted a line from the Yellowhead Pass to Burrard Inlet, which may be made out in any good map by following the course of the Thompson and Frazer rivers. By this line the Pacific coast will be reached in 1945 miles from Lake Superior, and it is already partly under contract. This is not a place to enter upon engineering details. I will only remark that greater difficulties have seldom been presented to human enterprise than must here be conquered. That peculiar feature in physical geography, the cañon or deep gorge, of which the Via Mala is an example familiar to many persons, is presented all over the region upon a scale of grandeur unsurpassed. When not perpendicular cliffs, their sides are in these latitudes seamed by avalanches on the largest scale; while the mountain torrents which rush down them defy navigation. Mr. Jarvis describes how on one occasion having walked into a hole, concealed by snow, the current caught his snow shoes, turning them upside down, and held him like a vice, so that it required the united efforts of all his party to extricate him.

There is a curious circumstance mentioned in this gentleman's narrative which deserves notice, as an instance of the successful reduction of a native language to writing, free from the difficulties which attend the use of the Roman alphabet. He met with a kind of notice-board or finger-post at the dividing of two tracks on the prairie, having upon it characters, which were entirely unknown to himself and his companions, and apparently to the Railway Department:—

They are, in fact, characters of a phonetic alphabet, invented forty years ago by a Mr. Evans, a Wesleyan missionary among the Cree Indians, and are extremely well adapted for expressing their liquid polysyllabic language. That they should have survived the generation to which they were first taught, and be still used for

communication on the plains, is a fact which would have given great gratification to their excellent author.[1]

The final decision of the Canadian Government to adopt Burrard's Inlet for the Pacific terminus of their railway, relegates to the domain of pure geography a great deal of knowledge acquired in exploring other lines: explorations in which Messrs. Jarvis, Horetsky, Keefer, and others, have displayed remarkable daring and endurance. They have forced their way from the interior to the sea-coast or from the coast to the Peace River, Pine or Yellowhead Passes, through country previously unknown, to Port Simpson, to Burke Channel, to the mouth of the Skeena, and to Bute Inlet, so that a region but recently almost a blank on our maps, which John Arrowsmith, our last great authority, left very imperfectly sketched, is now known in great detail, and I regret to add, the better known, the less admired. The botany has been reported on by Mr. Macoun, and the geology by Dr. Dawson, *pari passu* with its topography. I have great hope that the Section will receive from the last-named traveller in person some account of his many arduous journeys in the prosecution of geological research. Of these, the latest is the exploration of Queen Charlotte Islands, a part of the British possessions, very little known to most of us, although we had a communication on the subject in 1868. He regards them as a partly submerged mountain chain, a continuation north-westward of that of Vancouver's Island and of the Olympian Mountains in Washington Territory. An island, 156 miles long and 56 wide, enjoying a temperate climate, and covered with forests of timber of some value (chiefly *Abies Menziesi*), is not likely to be left to nature much longer. But the customs of the natives in regard to the inheritance and transfer of land are unfavourable to settlement, and will demand just and wise consideration when the hour comes. It is as much private property as any estate in Wales.

Mr. Dawson's report contains a vocabulary of the language, which presents this peculiarity, that the words expressing family relationship vary with the speaker. Thus 'father' said by a son is *haung*; said by a daughter, is *hah-ta*. 'Son,' said by a father, is *keet*; said by a mother, is *kin*. Evidently at some period the mothers were captives of a different tribe. It would be difficult to produce on the globe a more conspicuous example of the beneficent effect of missionary influence, combining industrial with religious instruction, than has been presented by the Tsimpsheean Indians at Metla Katla, under Mr. Duncan, a layman commissioned by the Church Missionary Society.

I must now call your attention to the remarkable explorations, little known in this country, of l'Abbé Petitot, also a lay missionary (*frère oblat*) of the Roman Catholic Church, in the Mackenzie River district, between Great Slave Lake and the Arctic Sea, a region which that Church has almost made its own. Starting sometimes from St. Joseph's mission station, near Fort Resolution, on Great Slave Lake, sometimes from S. Theresa, on Great Bear Lake, sometimes from Notre Dame de Bonne Espérance on the Mackenzie, points many hundreds of miles asunder, he has on foot or in canoe, often accompanied only by Indians or Esquimaux, again and again traversed that desolate country in every direction. He has passed four winters and a summer on Great Bear Lake, and explored every part of it. He has navigated the Mackenzie ten times between Great Slave Lake and Fort Good Hope, and eight times between the latter post and its mouth. We owe to his visits in 1870 the disentanglement of a confusion which existed between the mouth of the Peel River (R. Plumée) and those of the Mackenzie, owing to their uniting in one delta, the explanation of the so-called Esquimaux Lake, which, as Richardson conjectured, has no existence, and the delineation of the course of three large rivers which fall into the Polar Sea in that neighbourhood, the 'Anderson,' discovered by Mr. Macfarlane, in 1859, a river named by himself the Macfarlane, and another he has called the Roncière. Sir John Richardson was aware of the existence of the second of these, and erroneously

[1] The words, read by Archdeacon Hunter, are 'oomah maskemow pache oonahne aetahmoo,' and their purport is a direction. 'This road, come, oonahne flee thou.' He cannot make out *oonahne*.

supposed it to be the 'Toothless Fish' River of the Hare Indians (Beg-hui-la on his map.) M. Petitot has also traced and sketched in several lakes and chains of lakes, which support his opinion that this region is partaking of that operation of elevation which extends to Hudson's Bay. He found the wild granite basin of one of these dried up, and discovered in it, yawning and terrible, the huge funnelled opening by which the waters had been drawn into one of the many subterranean channels which the Indians believe to exist here.

These geographical discoveries are but a small part of l'Abbé Petitot's services. His intimate knowledge of the languages of the Northern Indians has enabled him to rectify the names given by previous travellers, and to interpret those descriptive appellations of the natives, which are often so full of significance. He has profoundly studied their ethnology and tribal relations, and he has added greatly to our knowledge of the geology of this region.

It is, however, much to be regretted that this excellent traveller was provided with no instruments except a pocket watch and a compass, which latter is a somewhat fallacious guide in a region where the declination varies between 35° and 58°. His method has been to work in the details brought within his personal knowledge, or well attested by native information, on the basis of Franklin's charts.

M. Petitot expresses his persuasion that the district of Mackenzie river can never be colonized—a conclusion no one, who has visited it, will be disposed to dispute; but he omits to point out that the mouth of that river is about 700 miles nearer the port of Victoria, in British Columbia, than the mouth of the Lena is to Yokohama, and far more accessible. It needs no Nordenskjöld to show the way. Its upper waters, the Liard, Peace, Elk, and Athabasca rivers, drain an enormous extent of fertile country, not without coal or lignite, and with petroleum in abundance. As the geological survey has not yet been extended so far, we are not fully acquainted with its mineral resources; but I can add my testimony to that of more recent travellers, as to the remarkable apparent fertility, and the exceptional climate of the Peace River valley. It is no extravagant dream that sees in a distant future the beneficent influence of commerce, reaching by this great natural channel, races of mankind in a high degree susceptible to them, and alleviating what appears to us to be the misery of their lot.

There are few subjects of greater physical interest, or which have received less investigation, than the extent to which the soil of our planet is now permanently frozen round the North Pole. Erman, on theoretical grounds, affirms that the ground at Yakutsk is frozen to a depth of 630 feet. At 50 feet below the surface it had a temperature of 28°·5 F. ($-6°$ R.), and was barely up to the freezing point at 382 feet. It is very different on the American continent. The rare opportunity was afforded me by a landslip on a large scale, in May 1844, of observing its entire thickness, near Fort Norman, on Mackenzie river, about 200 miles further north than Yakutsk, and it was only 45 feet. At York Factory and Hudson's Bay it is said to be about 23 feet. The recent extension of settlement in Manitoba has led to wells being sunk in many directions, establishing the fact that the permanently frozen stratum does not extend so far as that region, notwithstanding an opinion to the contrary of the late Sir George Simpson. Probably it does not cross Churchill river, for I was assured that there is none at Lake à la Crosse. It depends, in some measure, on exposure. In the neighbourhood of high river banks, radiating their heat in two directions, and in situations not reached by the sun, the frost runs much deeper than in the open. The question, however, to which Sir John Richardson called attention so long ago as 1839, is well deserving of systematic inquiry, and may even throw some light on the profoundly interesting subject of a geographical change in the position of the earth's axis of rotation.

The Saskatchawan was first navigated by steam in 1875, when a vessel of about 200 tons ascended from the Grand Rapid to Edmonton, 700 miles. There is, however, an obstacle at Cole's Falls, below Carlton House, which has led to a break of navigation, and a small steel steamer, originally intended for the Upper Athabasca, has recently been transferred to the Upper Saskatchawan; between

the two, it is now navigated from the Grand Rapids, near Lake Winnipeg, to the base of the Rocky Mountains. A steamer also plies regularly on Lake Winnipeg, and has ascertained many interesting particulars, of which we have hitherto been ignorant. Its greatest depth does not apparently exceed 100 feet. Its discharge has at last been followed by Dr. Robert Bell, down the Nelson river, to the sea. That gentleman reports the impediments to navigation to be insuperable, and a company has been very recently formed to make a railway from the lowest navigable point to the mouth of the Churchill river.

Our hopes of further light upon the history of the ill-fated Franklin expedition, based on information given by a Netchelli Esquimaux, to the American Captain Potter in 1872, have been again disappointed. An American search expedition landed at Depôt Island (lat. 64°), in the neighbourhood of which traces were reported, in August 1878, wintered there, and examined the country, as yet with no result, except a correction of the charts.

Hudson's Bay itself cannot fail at no distant day to challenge more attention. Dr. Bell reports that the land is rising at the rate of 5 to 10 feet in a century, that is, possibly, an inch a year. Not, however, on this account will the hydrographer notice it; but because the natural seaports of that vast interior now thrown open to settlement, Keewatin, Manitoba, and other provinces unborn, must be sought there. York Factory, which is nearer Liverpool than New York, has been happily called by Prof. H. Y. Hind, the Archangel of the West. The mouth of the Churchill, however, although somewhat further north, offers far superior natural advantages, and may more fitly challenge the title. It will undoubtedly be the future shipping port for the agricultural products of the vast north-west territory, and the route by which emigrants will enter the country.

Before leaving this quarter I must allude to the praiseworthy efforts of some of the Western States, especially Nebraska and Minnesota, to encourage the planting on the great plains by premiums, in which they have been followed by our own Province of Manitoba. Many years must elapse before the full climatic effects can be realized, but in time they cannot be doubtful, and with the impending disappearance of the buffalo will disappear much of that arid treeless region, embracing nearly 600,000 square miles, which he now wanders over, and assists to keep bare by so doing. On the other hand, the short-sighted and destructive habit of burning off the prairie grasses to promote a young growth, increases with settlement, and is chargeable with incredible mischief. These fires have the curious effect, when they extend into wooded regions, of helping to exterminate the more slow-growing and valuable descriptions of timber, and favouring the prevalence of the more worthless quick-growing kinds. But the Indians are even more chargeable with them than the whites, and the traveller encounters few more melancholy sights than a forest of charred and lifeless trunks extending over an area as large as a county, the fruit perhaps of a signal from one band to another.

A discourse on American geography would be incomplete without reference to that great design of piercing the Isthmus of Panama, with which Count Ferdinand de Lesseps has connected his name. Out of the conflict of about ten competing lines, the oldest and the youngest alone survive. The route by Lake Nicaragua appeared possible even to Cortez. It was accurately surveyed nearly seventy years ago, and the estimates, although they have grown alarmingly, are still within practicable limits. It has the preference of the highest authorities in the United States. Its total length would be 180 miles, including 56 miles of lake navigation, with a summit level, to be attained by lockage, of 107·6 feet.

The Panama route would shorten the canal to one-fourth of this length, and it is a cardinal point with its author to dispense altogether with locks. As we expect to be favoured by the presence of Lieut. Bonaparte Wyse—M. de Lesseps' coadjutor—I need say no more, except that the enthusiastic reception given to M. de Lesseps here in Swansea, not many weeks ago, is sure evidence that this great industrial centre takes a keen interest in his project from a commercial point of view; and we may safely leave capitalists, engineers, and diplomatists to fight out their battle, only concerned that by one route, if not by both, the world may reap in our day

the vast benefit it already owes, in another quarter, to his genius and indomitable perseverance.

One of the most interesting questions in the whole range of geography still awaits positive proof or disproof in this region. I refer to the often asserted existence of a native race in Central America which holds no communication with Europeans, and preserves its ancient language, religion, and civilisation unchanged from the time of the Spanish Conquest. Antecedently so improbable as to be well-nigh incredible, it found credit with Mr. Stephens and Mr. Catherwood and Mr. Norman. A later traveller, Captain Carmichael, expressed, at this Association in 1870, his firm belief in it; and I will, with your permission, read an extract from a letter dated January last, which I received from that enthusiastic explorer, Dr. Le Plongeon, who has been for several years engaged in investigating the ruins of Central America.

'I have been told that there are many tribes in the interior of the country that have had but little contact with the Spaniards, and therefore have retained the purity of their language. This causes me to tell you here that the report—which many think hypothetical, of a vast extent of country, some assert 500 miles, comprised between Tabasco, Gualtimala, Peten, and Yucatan, very mountainous, well-nigh inaccessible, that is inhabited by the remnants of various warlike tribes, the Chinamacces, the Laucaerones, the Itzaks, and others, who flying before the Spaniards, have fortified themselves in very rich valleys, where they live to the present day as their fathers, at the time of the arrival of the Spaniards, and speak the pure unadulterated Maya—is not far from being true. I have inquired from parties who have lived in the neighbourhood of the Tierra de la Guerra, as they call it, and learn that people coming from the unknown regions are sometimes seen in the villages of the neighbourhood, where they barter tobacco, cocoa, and other products of their industry, for whatever they want; that of late some came to hire on the farm as labourers, but will not allow any white to penetrate their stronghold.'

Tierra de la Guerra is an old designation for the region in which the boundaries of Honduras, Yucatan, and Guatemala meet, and which contains some twenty-five or thirty thousand square miles, an area quite extensive enough for small aboriginal communities to be hidden away in it; and, if as Dr. Le Plongeon thinks, the long-sought key to the Mexican hieroglyphics should be preserved among them, there is a brilliant reward for the first scientific traveller who, without shedding blood, can penetrate into their fastnesses. We shall, I trust, hear more of this region from a gallant and enterprising traveller, the Colonial Secretary of British Honduras, who has already penetrated its outskirts, and wants nothing more than a little aid and encouragement to advance beyond them. In a recent letter to me, Mr. Fowler says:—

'On the east coast of Yucatan, not far from the sea-coast, are the ruins of three cities, and close to our own frontier is a ruin which, the Indians tell me, contains plenty of mural paintings on the inside walls of the chambers. All these ruins are under the control of the Santa Cruz Indians. The chiefs of these Indians lately visited Belize and were shown much attention. I had them particularly in my charge. They received a Martini-Henry rifle each and we swore mutual confidence in each other. They invited me to their country, promising me a safe conduct, and gave me leave to visit any ruin and take away what I liked.'

That such an opportunity should be lost for want of a very moderate sum to defray the expenses of an expedition would be a matter of regret, which all present will share; and I am not without hopes that ways and means may be raised, through the co-operation of those who are interested in the subject from an historical, as well as a geographical point of view, to enable Mr. Fowler to carry out his project.

Mr. Edward Whymper, whose recent mountain ascents in Ecuador have roused the interest of geographers and Alpine climbers in so high a degree, and whose presence to-day we had some reason to expect, is detained at Guayaquil. Fortune has favoured him to the last. He made a second ascent of Chimborazo in July, and after passing the night at an elevation of 15,000 feet, reached the summit in

time to witness a magnificent outburst of Cotopaxi, 60 miles distant. The hot ashes were wafted to Chimborazo in such quantities as to cover the snow around him, and to produce an effect which he compares to the appearance of a newly-ploughed field.

It appears probable that we shall owe to America the solution of a question which, even within the limited area of these islands, often occupies our Courts of Law, and troubles us in daily life. I mean a definition of civil time. We have an extreme difference of time between Yarmouth and Valentia of about $48\frac{1}{2}$ minutes; but the merchant at San Francisco finds himself $3\frac{1}{4}$ hours behind his correspondent in New York, and the consequence has been an irregular acknowledgment of no less than seventy-five local standards of time on different railways in the United States. These it is now proposed to reduce to five, of exactly one hour interval, which would equally suit the Dominion of Canada. Mr. Sanford Fleming, late Engineer-in-Chief of the Canada Pacific Railroad, advocates the still bolder measure of adopting the meridian of 180°, as a meridian for railway and telegraph time all over the world. It is not unworthy of this Section to aid in the preparation of the public mind for the legal adoption of prime meridians in this country at about ten-minute intervals. Thus Greenwich time might rule from Yarmouth to Winchester; Bath time from Winchester to Exeter, and so on; the first step towards which will be substituting meridians at $1\frac{1}{4}°$ interval, corresponding to five minutes of time, for the unmeaning lines at 1° or 5° of angle, which are drawn on school maps at present.

I shall, perhaps, be accused of poaching on the manor of a brother President, if I venture to allude to another subject which belongs rather to the Geological Section. But a railway guide is surely a geographical manual, and in the American Geological Railway Guide of Mr. Macfarlane, we have a model and example of what may be done to disseminate knowledge, which I think worthy of passing notice. This work tells the traveller, and the resident no less, the chief geological characteristics of the neighbourhood of every railway station in the United States. Is it extravagant to suppose that the same information, with the addition of the name of the county, the height above the sea, the prevailing industry, the population, the rainfall, the climate, and other constants, may be some day furnished by our great companies to the intelligent strangers who spend so many weary minutes in waiting at every station?

Turning now from a quarter on which I fear I have nearly exhausted your patience—from the West to the East. It is now nearly forty years since the corps of Royal Engineers was first associated in the exploration of Palestine by the employment of Captain Symonds, R.E., to determine the depression of the Dead Sea. The recent completion of the great map of that country is a performance whose unrivalled Biblical and topographical importance should not blind us to its geographical interest. The first surveyed of all known lands, it is also the last.

> Siloa's brook that flowed
> Fast by the oracles of God

is traced again, and the surprising local accuracy of the sacred writers established upon testimony beyond dispute.

The British survey, as you are aware, has been limited to the country west of the Jordan, an American Association having charged itself with the survey east of that stream. This is not yet published; but I trust that we shall have from Mr. Laurence Oliphant an account of a part of that little-known region, from which he has lately returned.

Operations of war have been in all ages fruitful of geographical knowledge. Many an old soldier of Alexander, we may be sure, was cross-examined by Eratosthenes; many a centurion of Hadrian related his weary marches in Gaul or Britain to Ptolemy, before those ancient geographers acquired the imperfect knowledge which served the world for so many centuries. The first legion that crossed the Alps accomplished a feat as arduous as the passage of Shutargardan or the

Balkans, but it left us no record. To our own and the Russian Topographical Staff in Central Asia we owe, on the contrary, a series of explorations conducted under every difficulty, which must vastly facilitate the access of commerce to those distracted regions. Referring here to the former alone, they may be divided into three groups:—

1. Southern Afghanistan, embracing Quetta and Candahar.
2. The Kurram valley and generally the south of the Safaid Koh range.
3. The north of the Safaid Koh range, including the valley of the Kabul river and that city itself.

In the first of these an entirely new route through the villages of Tal and Chotiali, crossing several mountain passes, was followed by Major-General Sir M. Biddulph's column, and surveyed by Captain T. H. Holdich. Much new country was also surveyed by Lieutenant-Colonel W. M. Campbell between Pishin and the Afghan desert. This officer thrice crossed the table-land of Toba, and by means of the field electric telegraph, has determined the difference of longitude between Quetta and Candahar.

On the south of the Safaid Koh range we have at least 3000 square miles surveyed by Major R. G. Woodthorpe, embracing the Shutargardan pass and the range which divides the Kurram from the Khost valley. This officer, accompanied by Captain Martin, ascended in 1878 the highest peak on the Safaid Koh range (Sikaram, 15,622 feet), but unfortunately was disappointed of observations, by the hot-weather haze, which enveloped the peaks of the Hindu-Kush. Mr. G. B. Scott, a civilian surveyor, was more successful, and obtained observations to all of them.

On the north of the Safaid Koh range over 2200 square miles of new country were surveyed in 1878–9. The Shinwaries and Khagianis have, however, an insuperable aversion to plane tables and theodolites, and it was in no spirit of kindness that they gained for the gallant Captain E. P. Leach, R.E., his Victoria Cross. Less has been learnt about their country than could be wished. I am not over-stating the services of our Topographical Staff in Afghanistan in estimating the aggregate of ground covered by their surveys or sketches at 140,000 square miles, and we have, through Major Tanner, got a little information respecting the almost unknown land of Kafiristan, lying to the north of Jallalabad. Disguised as a Kabuli, this gallant officer entrusted himself to a friendly Chugani chief, and penetrated some distance into that rugged country. He says of the principal village that the houses are piled one above another, and every beam, doorway, and shutter carved in a most elaborate manner. The designs, he adds, are crude, but such a mass of carving he had never seen before. The taste reminds us curiously of that of the mountaineers of Switzerland and the Tyrol. I regret that the limits of an address do not permit justice to be done to the services of these gallant officers.

In Zululand about 9000 square miles of country have been triangulated, and the details filled in, to some extent, at our Intelligence Department, from the numerous sketches of the staff; no such systematic survey was, however, attempted in this quarter as in Asia—a fact to be regretted, when we remember the excellent opportunity which the military occupation of a country affords for combined explorations.

In Central Africa we have the information given to Commander Cameron by his native guides, in 1874, that a river they called the Lukuga, which he descended four or five miles, is the outlet of Lake Tanganyika, confirmed and placed beyond dispute by the Rev. E. C. Hore, of the London Missionary Society, who entered it in April, 1879, found it free from the obstructions which arrested Cameron, and was able to go further down. Since which time, and quite recently, its course has been followed by Mr. Joseph Thomson, almost to its junction with the Lualaba. The discovery is of extreme interest from every point of view, especially as pointing to the probable line of future communication of the regions bordering that great inland sea, with the Atlantic, although the river itself, at least after the rainy

season, is reported to be utterly impassable for canoe or boat of any description. The traveller himself, as you are aware, embarked for England on July 28, and doubtless will, if he shall arrive in time, afford us an opportunity of congratulating him on the safe accomplishment of one of the most brilliant and successful African expeditions on record. The most youthful of African travellers, for he is only 22 years of age, Mr. Thomson has carried out every point in the programme laid down for his late lamented chief, Mr. Keith Johnston; has done it admirably; and done it at a very moderate cost.

I hold in my hand, by favour of the Royal Geographical Society, and the kindness of my friend Mr. Bates, copies of letters received within these few days (the last is dated Zanzibar, July 19), giving an account of his adventures, which are many, since January last. They will appear in full in the next number of their 'Proceedings'; but I am sure I may anticipate their publication by reading a few extracts presently. They are rendered more than usually interesting by the melancholy fate which has since befallen Captain Carter, whose genial welcome at Karema he records.

Time does not permit me to follow all the phases of that new-born activity which is establishing centres of exploration and of civilisation at every great lake in Africa. The Belgian Expedition, conducted by Mr. Stanley, and the Baptist Missionary Expedition from San Salvador or Congo, are still aiming at the same point, viz., to reach Stanley Pool, above the falls, on the river Congo, the first by ascending the river, the latter by overland route, by way of Makuta or Zombo. The latter have met with great opposition at Makuta, and by the last account had not got within 100 miles of the Pool. That munificent benefactor of African missions, Mr. Robert Arthington, of Leeds, has paid a sum of 4000*l.* to the Baptist Society with a view to placing a small steamer on the river as soon as practicable, of establishing stations on the Ikelemba and M'bura rivers, and of opening communication by the latter with Lake Albert Nyanza. Much of this country is entirely unexplored.

The road from Dar-es-Salaam on the east coast to Lake Nyassa, about 350 miles, has been completed through the coast jungle. Mr. Beardall, the chief engineer, has located the first section of about 100 miles to the valley of the Rufigi, and proposes to make use of the tributary river Uranga as far as navigable, up stream, towards the mountains which border the lake, before resuming his road-making. The highways of Central Africa, whether by land or water, exist as yet only in the hopes of philanthropists and the dreams of commerce, and I fear we must include among the visions, that artificial sea which some geographers have proposed to make by conducting the waters of the Atlantic or the Mediterranean into depressions known to exist in the great Sahara. The subject has been examined by the Chevalier Ernst von Hesse-Wartegg, an Austrian traveller, who is prevented by illness from joining our meeting and giving us a communication on the subject. Meanwhile, it appears to be tolerably well established that wells can be sunk almost anywhere, each becoming a centre of vegetation and productiveness.

I feel, ladies and gentlemen, that I have detained you from the business of the Section an inordinate time. But then I may remind you that when the British Association last met at Swansea this Section (which was then combined with that of Geology), escaped an Address altogether. A generation has passed away since; of the eminent men then present in office some half-dozen alone remain, and in the retrospect it is so natural to take, the growth of geographical information stands out in remarkable prominence. Still—

> The cosmographer doth the world survey,

and finds an illimitable field for the improvement of old, or the acquirement of new knowledge. Better methods of instruction, better books, and, above all, better maps, are changing the aspect of the study to the young, every traveller who settles one question raises others for his successors, so that 'no man can find out the work that God maketh from the beginning to the end.' Its perpetual youth is the charm of our science; may it also be my excuse.

The following Papers were read :—

1. *Latest News of the Royal Geographical Society's East African Expedition under Mr. J. Thomson.*

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2. *Through Siberia, viâ the Amur and the Ussuri.*
By the Rev. HENRY LANSDELL, *F.R.G.S.*

This paper described a journey (undertaken with the object of visiting prisons, hospitals, and charitable institutions, which were found to be in a much better condition than is generally supposed) through Siberia, from the Urals to the Pacific, by a route largely new: namely, from Ekaterineburg to Tobolsk by horses; thence by steamer on the Irtish and Obi to Tomsk: again by horses to Barnaul, Irkutsk, Kiakhta (steaming across Lake Baikal), across the Trans-Baikal province to the Shilka: then by steamer to the Amur: down its entire length to Nikolaefsk; and subsequently returning southwards, by the Ussuri, Sungacha, and Sooifoon to Vladivostock.

On reaching the Obi, on the 62nd parallel, the author found on June 8th comparative winter, or leafless spring; the thermometer falling at night to 35°, but rising to 75° Fahr. by nine a.m. Fine weather set in a week afterwards and continued all across Asia. Here live ducks were offered by the Ostjaks for five farthings each, large fish called *yass* for 1½d. a pair, and pike for a farthing each. Milk cost 2½d. a bottle, but young calves in remote villages could be purchased for sixpence each. The belt of rich black earth in the region immediately north of the Altai lets for 3½d. per acre, and from it wheat may be purchased for about one-twentieth its cost in England. Still further north, in the forest region, rich in excellent timber and fur-bearing animals, meat was bought up wholesale in 1877 at less than a halfpenny per English pound; whilst in the most northerly region, that of the *tundras,* the rivers are so full of fish that one of the ordinary difficulties of the natives is to avoid breaking their nets with the weight of the draught. The fish thus caught are, in the winter, frozen and sent more than 2000 miles, to St. Petersburg, where a very moderate price realizes for the fisherman a profit of nearly a hundred per cent. These prices should be borne in mind in connection with the proposed trade between Siberia and England by the rivers Obi and Yenesei, and through the Kara Sea.

Mr. Lansdell reached Tomsk on the 10th June, having accomplished a journey of 5200 miles in 26 travelling days; and then made a *détour* of 600 miles to Barnaul, through a singularly rich and productive country. Irkutsk was reached after a posting journey of 1040 miles, on the 6th July. After crossing Lake Baikal, and making a *détour* to the Chinese frontier at Kiakhta, the hilly steppes of the Trans-Baikal province were crossed through Chita and Nertchinsk to Stretinsk. In the neighbourhood of Nertchinsk are the mines in which prisoners are popularly supposed to be killed by inches, living amid quicksilver fumes. Inquiry into this matter failed to convince the author that there is a quicksilver mine in Siberia, and when he inquired of released prisoners who had worked in the mines concerning such alleged enormities as keeping them under ground entirely, they distinctly denied the truth of such charges. The author himself visited the convict gold-mines at Kara, 70 miles down the Shilka from Stretinsk. Kara is a penal colony with upwards of 2000 convicts (including a few for political offences), condemned to hard labour in the gold mines. The labour is done on the surface and consists in digging earth and carting it away to be washed. The hours of convict labour, however, are shorter than those of free labourers in the same mines; and in the winter, the ground being frozen, the prisoners have little or nothing to do. Their weekly allowance of food weighs nearly double that given to English convicts, and after a certain time they are allowed to live with their wives and families before being settled as colonists.

The scenery of the Shilka compares by no means unfavourably with the Rhine.

After a course of 650 miles it unites with the Argun at Ust Strelka, and forms the Amur. From Ust Strelka to its mouth the Amur has a course of 1780 miles, with a fall of 2000 feet; but if the Argun be regarded as the head-quarters of the river there must be allowed to the Amur a length of 3066 miles, and a fall of 6000 feet. At Ust Strelka the river is 1100 yards wide, and ten feet deep. At Albazin, 160 miles lower, it contracts to 500 yards, but the depth increases to 20 feet. It then runs 400 miles to the south-east and passes Blagovestchensk, the left bank from Ust Strelka being Russian, and the right bank Chinese territory. At Aigun the river increases to a mile in width, and at Pashkova commences to flow through the Bureya Mountains in a stream 900 yards wide, and from 110 to 80 feet deep. After this the stream widens up to the confluence of the Ussuri which flows into the right bank of the Amur at Khabarofka, 1123 miles from Ust Strelka. From Khabarofka, Mr. Lansdell descended the Amur 600 miles to Nikolaefsk. The river now widened in some places to three miles in a single channel, and where islands intervened its greatest breadth was as much as twelve miles. On the third day from Khabarofka the traveller reached Michailofsky situated in the district whence is produced the corn of the lower Amur, (which amounted in 1878 to 3276 tons, besides 811 tons of potatoes).

On the last day's travel, Mr. Lansdell saw at Tuir some Tatar monuments with Sanscrit words written in Chinese, Nigurian, and Thibetan. It is said to be the site of an ancient Lama monastery. The characters on the principal stone reminded the observer of a palimpsest manuscript of which only the upper characters had been deciphered.

The author reached Nikolaefsk on the 13th, and stayed to the 30th August, then returning to Khabarofka. This gave him ampler opportunity of seeing the natives—especially the Gilyaks and Goldi. The Gilyaks inhabit the lower part of the river, are small in stature, and live almost entirely on fish. They have little notion of a Supreme Being, and are commonly said to worship the bear (this, however, they denied). So far as they have any religion at all, it is that of Shamanism, common to most of the aborigines of Northern Asia, the chief feature of which appears to be that of a priest performing incantations, and connected with which is the drinking of brandy to intoxication. They use also rough idols of wood.

Higher on the Amur, and up the Ussuri dwell the Goldi, numbering 6000. They are slightly superior to the Gilyaks, but both people buy their wives, and practise polygamy; a wife costs eight or ten dogs, a sledge, and two cases of brandy. The favourite winter dresses of Goldi and Gilyaks are made of the skins of their dogs, but in summer they use dresses of fish-skin. The Russian Missionary at Khabarofka told Mr. Lansdell that in 23 years he had baptized in the neighbourhood more than 2000 heathens.

On the 4th September, the traveller came the second time to Khabarofka, whence he proceeded up the Ussuri. This river is nearly two miles wide at its junction with the Amur. In ascending, the right bank is Chinese territory, the left Russian. The Chinese bank is for the most part flat: but the horizon is bounded by low mountain peaks. The left, or Russian bank, is mountainous and wooded. Sometimes the mountains retire, leaving a rich bottom land of English park-like scenery. The habitations passed on the Ussuri were few and far between. Most of the Russian dwellings consisted of Cossack *stanitzas* and pickets, placed there to guard the frontier. The Ussuri is navigable several miles beyond Busse, and could a railway be made from Vladivostock to its most southern navigable point it would be of the greatest importance to the fertile lands of the lower sea-coast province. The total length of the Ussuri is 497 miles. The upper part of the stream is rapid, and below the confluence of the Sungacha also it is swift; but towards the mouth it has a current of two knots only. It presents no special difficulties to navigation.

On the 9th September, Mr. Lansdell at Busse entered the Sungacha, which is from 100 to 110 feet wide, and from 50 to 80 feet deep. It is very tortuous and winding, having a bend in each half-mile; the water is so muddy as to be unuseable for cooking, but is full of fish and also of turtles, and the banks abound with

game and also with tigers. On the evening of the second day the traveller arrived at Lake Khanka. There were two Chinese houses, of which not a dozen had been seen all along the Ussuri; thirty-six Russian stations in all were passed. Lake Khanka is 65 miles long, and from 21 to 26 miles wide. Its shores, with the exception of the south and south-east, are wooded, but not mountainous. After steaming across it during the night and arriving at Kamen-ruibaloff at dawn on September the 11th, Mr. Lansdell had to drive nearly 100 miles in the roughest of conveyances to the river Sooifoon, through a country singularly fertile, but almost uninhabited. The journey was accomplished by the evening of the second day, and on reaching Rasdolnoi there was found a small steamer to carry him 30 miles on the Sooifoon to the Amur Bay; where he was transhipped to a larger steamer, which brought him to Vladivostock—thus finishing his journey from London of 11,555 miles.

FRIDAY, AUGUST 27.

The following Papers were read:—

1. *The High Road from the Indus to Candahar.*
By Sir RICHARD TEMPLE, Bart., *G.C.S.I.*, *C.I.E.*, *F.R.G.S.*

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2. *Six Years' Exploration in New Britain and neighbouring islands.*
By WILFRED POWELL.

After referring to the great variety and immense value of the products of these islands to our markets, and the corresponding benefit to the natives likely to accrue from the establishment of English trade, Mr. Powell remarked that they were very anxious to obtain the articles dispensed by English traders, and to have traders living with them. He then gave a slight sketch of the first discoverers and geographical position of New Britain (situate between the eastern extremity of New Guinea and the Solomon Islands), which has a coast line of nearly 400 miles, from Spacious Bay on the east to the island of Willaumez on the west. The natives were at one time apparently identical all over the island, though now varying in different parts of it. They are subject to a disease called 'Buckwar'; bigamy exists among them, and they purchase their wives; their money ('Dewana') consists of small cowries, which are strung together, a hole being made through the crown of the shell; payment is made with these by measurement, and not by weight. Mr. Powell described the arms of the people as carried in war, their method of making stone-clubs, and their different methods of making war, which are marked by great treachery, and accompanied by decided acts of cannibalism; also their civil ruler ('Dook Dook'), and his rights of succession and manner of dispensing justice; their superstitions, marriage rights, dances, and special costumes (including a human skull mask), surgery, bone-setting and implements, musical instruments, houses, fisheries, &c.

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3. *Three Years in South-East New Guinea.*
By the REV. W. G. LAWES, *F.R.G.S.*

The author's observations were made during a residence at Port Moresby and Hood Bay, and comprised notes on the geographical and physical features of the district between Yule Island and East Cape; the flora and fauna, climate and natives, with a description of the houses, canoes, occupations, habits, moral condition, and religious beliefs of the people inhabiting the Port Moresby and Hood

Bay district. These remarks were illustrated by photographs of the natives and their dwellings, taken by the author, and by specimens of native manufactures, weapons, &c., collected by him.

The country about Port Moresby was described as poor and barren, though possessing many features of natural beauty. The natives present a great diversity of race and habits, speaking twenty-five different dialects in an area of 300 miles. Their houses are built on piles, and the stone age still prevails with them. Their moral condition is low; but the author spoke in high terms of the kindness and hospitality experienced at their hands.

The resources of the district are as yet undeveloped, and at present no commerce is carried on with the people. The climate has proved unhealthy to Europeans, and will interfere seriously with any attempt at colonisation.

The author concluded with an appeal, in the interests of religion, science, and commerce, to preserve peaceful relations with the aborigines.

SATURDAY, AUGUST 28.

The Section did not meet.

MONDAY, AUGUST 30.

The following Papers were read:—

1. *Results of the Portuguese Expedition in West Central Africa. By* Capt. H. Capello *and* Lieut. R. Ivens.

2. *Recent Travels in Trans-Jordanic Palestine. By* Laurence Oliphant.

This paper contained notes of a journey undertaken during the spring of last year through the provinces of Jaulan, Ajlun, and Belka, to the east of the Jordan. Crossing the Jordan at its source, Mr. Oliphant struck south-east from Bamai, visiting the new Circassian colony of Kuneitereh. Then crossing the fertile pasture-lands of Jaulan, the ancient Gaulanitis, or Jolan of the Scriptures, he kept along the eastern base of the Jebel Hesh range, ascending Tel-el-Teras, its most southerly peak. Thence in an easterly direction to Sheikh Sa'ad, where the fountain and sacred stone of Job are resorted to, more especially by negro pilgrims from Soudan and other parts of Africa, and form 'holy places,' much venerated in the neighbourhood. Thence to Tel-Asherah, which the author thinks he has satisfactorily identified as the site of Ashtaroth Karnaim, and thence by way of Mesarib to Irbid (Arbela), and Beit-er-Ras, the ancient Capitolias, at both of which places are interesting remains of architecture of the Greek and Roman type, common to this part of the country, in the first and second centuries after Christ, and where the stone houses of the Jefnide and Ghassanide Arabs still remain to testify to their superior civilisation. Both at Tel-Asherah and Irbid, however, the sub-structure bears marks of an antiquity anterior to the Christian era. From Capitolias the south bank of the Yarmuk was followed to Gadara, the extensive ruins of which are too well-known to need description. Thence in a south-easterly direction into the forest-clad mountains of Gilead and by a circuitous route to Ajlun, the principal village of the province

of that name, dominated by the Saracenic castle of Kalat-er-Rubud. Thence easterly to Jerash. Thence to Salt, and from Salt in a due easterly direction to the interesting and little known ruins of Yajuz; thence to Kalat Terka, a station on the Hadj road from Damascus to Mecca, and probably the site of the ancient Gadda. Thence south-west to Rabboth Amman and back to Salt. From Salt he also visited the interesting ruin of Arak-el-Emir, the fortress of Hyrcanus. The whole country traversed, was, excepting in its eastern sections, either pasture, wooded, or arable land, and capable in the highest degree of development; while there can be no doubt that in the unexplored mountainous region traversed by the Upper Yabbok ruins remain yet to be discovered, and sites to be identified, which will contribute for some years to come to make the whole of this country, already so replete with historical association, a most interesting field of research.

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3. *On Pictorial Aid to Geographical Teaching. By* G. G. BUTLER, *M.A.*

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4. *Notes on a Journey from Canton to Kwei-Yang-Fu up the Canton River. By* W. MESNY.

Mr. Mesny, a gentleman from Jersey, who has passed many years in the interior of China in the service of the Chinese Government, and who accompanied Captain Gill from Ch'êng-Tu to Bhamò during his journey across China to Burma, has communicated through that officer particulars of his voyage up the Hsi-Ho or Canton river to Kwei-Yang-Fu in the province of Kwei-Chou, not before made by any European.

Mr. Mesny started from Canton on March 9, 1879, in a native junk, ascending the west river past Fu-Shan (the 'Fat-Shan' of W. & A. K. Johnston's map), and entering the main Hsi-Ho (Si-Kiang of Johnston) at San-Shui-Hsien. Here the river is 200 yards wide, and deep enough for steamers of 1000 tons; its banks are fertile and well-cultivated. After passing Shao-Shing-Fu (Chow-King), the frontier of Kuang-Si was reached at Wu-Chou-Fu (Oo-Chow), on the junction of the Fu-Ho and Hsi-Ho. This city is the centre of a considerable import and export trade, and is visited for commercial purposes by the aboriginal Miau-Tze from Kwei-Chou, with strange costumes and incomprehensible tongue, who are looked on with contempt by the people of the great central nation. Even now there are here stores for foreign goods which have managed to pass the Lekin or octroi barriers so numerous between Canton and Wu-Chou-Fu. These barriers afford little benefit to the revenue, being used by greedy officials as a means of extortion; and they cripple trade by increasing the cost of articles in proportion to the distance of carriage. Wu-Chou-Fu may, however, yet become a good treaty port for Kuang-Si, Kwei-Chou, and some parts of Hu-Nan and Yün-Nan, as light-draught steamers for towing purposes could come up with cargoes all the year round. Mr. Mesny met with civil treatment from the people, though the magistrate endeavoured to keep him away by attempting to excite his fears.

After a journey of twenty-one days up the Fu-Ho (Kwei-Fong or Cassia), the traveller reached Kwei-Lin-Fu (Kuei-Ling), the provincial capital of Kuang-Si, on June 23. This river is not likely to be used for steam traffic, owing to its shallow rapids. The cities on it are ruinous, and occupied chiefly by new-comers. Rice and other cereals, and sugar cane, are much cultivated, and the country above Ping-Lo-Fu is very picturesque, the hills sometimes having large caves which pierce them, showing the sky through. The people are greater flesh-eaters than those of other provinces, and the women do not as a rule cramp their feet.

After a stay of a week, Mr. Mesny reached the Pei-Sha-Kiang, having crossed a plateau by water with an ascent of eight and descent of fifteen locks. There a large irrigating wheel, lifting water 30 feet above the river level into troughs, was seen. On the third day from Kwei-Lin-Fu the main west river (Hsi-Ho) was again struck, near Liu-Chou-Fu (Lioo-Chow), now very quiet and partly in ruins. The

width, depth, and slight current of the river appear to favour steam navigation, and though the branch starting near Yün-Nan-Fu is much the longer, this one is considered the principal by the Chinese, who give the preference to the one having the greater number of junks. Trade therefore was probably more prosperous here in former days. Ascending the river to Liu-Cheng-Hsien (Lioo-Chin), where it again forks east and west, the traveller chose the Yung-Ho or eastern branch, reaching Yung-Hsien on the fifth day from Liu-Chou-Fu. This is a flourishing city, and would make a first-rate terminus for steam navigation from Hong-Kong. Still ascending the Yung river, the shallows and rapids of which began to obstruct navigation, Ku-Chou-Ting, an important frontier city of Kwei-Chou, was reached in ten days, the country traversed being entirely inhabited by a peculiar tribe of Miau-Tze called Tung-Kia, subsisting principally on a very glutinous kind of rice called No-Mi, and living in two-storeyed houses, of which the lower storey is occupied by cattle, and the upper is almost destitute of furniture.

At Ku-Chou-Ting, the smallest boats obtainable had to be used, and in eight days the head of all navigation was reached at San-Kio, or Li-Miao-Chou, as it is called officially. An overland journey of eight days brought the traveller to Kwei-Yang-Fu, entirely through the country of the Miao-Tze, who are gradually being displaced by Chinese immigrants, who follow the water-way, and drive the natives further back into the country.

Mr. Mesny considers that steamers might ascend from Hong-Kong to Yung-Hsien in three or four days without going to Canton, and that a railway might be laid from Yung-Hsien to Kwei-Yang-Fu, *viâ* Li-Po-Hsien, Tu-Shan-Chou, Lo-Hu, and Tein-Fan-Chou. This would, in his opinion, be remunerative if the mines of the province were opened, and the establishment of a trading line in this direction would also tend to the opening up of the extensive and rich copper mines of Yün-Nan, to which the direct road is by the Hsi-Ho.

Mr. Mesny gave some interesting details of the habits, customs, and superstitions of the people amongst whom he travelled, *e.g.* Miao-Tze, with a piece of board fixed with resin to their crowns for a three years' period; Yao-Shun, with their temples quite bald; and Chung-Kia of two tribes, Lo and Wei, agriculturists, excessively devoted to whiskey distilled from the glutinous rice No-Mi, and with hard-working women, whose morals until the birth of their first child in wedlock are peculiarly lax, and who sacrifice bulls and dogs to appease the manes of their ancestors.

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5. *The Dutch Indian Government Exploring Expedition in Borneo.* *By* Carl Bock.

In June 1879, Mr. Bock was commissioned by the Dutch Indian Government to explore the east and south parts of Borneo. In the beginning of July he arrived at Tangarong, the residence of the Sultan of Koti, to whom he at once made known his plans of exploring the northern and southern parts of Koti, and of attempting the overland journey to Banjermassin (the latter journey had been in vain attempted three times).

The Sultan, after some demur, furnished him with an interpreter for the Dyak language, and also put at his disposal a large prau, or canoe. Mr. Bock, with his twenty-five followers, left Tangarong on August 10, and navigated the great Mahakkan river up as far as Moeara Kaman.

The banks of this river are very thinly inhabited, and only by the Malays and Bugis. The great drought, which visited parts of Borneo and other islands two years ago, had made terrible havoc in the forest. For miles the trees were killed by it, and nothing but their dead trunks was visible—a strange sight in the tropics, where the eye is accustomed to behold an everlasting summer. From Moeara Kaman he went up the Moeara Klintjow river. The country is here less inhabited; for a whole day, and even more, rowing along the banks of the river, no hut was visible; and the only sign that occasionally enlivened the scenery was a graceful snake-darter or a group of inquisitive monkeys. On the 21st, Longwai, the largest Dyak village, was reached.

The natives were at first shy and suspicious; but after a while Mr. Bock managed to get on good terms with them. These Dyaks are, like the rest of the other tribes in Koti, inveterate head-hunters; but in other respects good and honest people. The 'head-hunting' belongs to the Dyak religion, and is a custom ('adat') established from ancient times. For this reason the traveller who moves amongst such tribes is in continual danger. The different tribes have often petty wars, and the attacks are mostly made in the night.

From Longwai Mr. Bock went further north, in order to find the Orang Poonan (also called Olo-Ott) or forest people, whom no European had before seen. These savages, on the very lowest scale of civilisation, are exceedingly shy; they live in troops of six to twenty, have no huts nor any fixed dwelling-places, but roam about the immense forests, and feed upon monkeys, boars, birds, serpents, and wild fruits. They seem to be provided with strong digestive organs, as they eat with great appetite the thick roasted hide of the wild boars and monkeys (*Nasalis larvatus.*)

The women are especially light in colour, and both sexes go almost naked. They have a very scurvy appearance, and are very dirty; but the rumour that the Orang Poonan are furnished with a caudal appendage is entirely false.

Having returned to Tangarong, Mr. Bock prepared for his overland journey—over 700 miles, and left Tangarong with forty-one men and three canoes, being in every respect well fitted out. The Pangeran (or Prince) Sokmaviro accompanied the traveller, as well as a Malay interpreter for the Dyak language. The route was again up the great Mahakkan to Moeara Kaman, where the mosquitoes were such a plague that the expedition thought of returning. The next village in the interior was Kotta Bangoen—the largest in Koti—with more than a thousand souls. The inhabitants are all Malays and Bugis, who carry on a considerable trade in rattan, gutta percha, wax, and 'saroeng boeroeng' (edible birds' nests). It must be remembered that all the Dyak tribes inhabit the tributary rivers of the Mahakkan, to the far interior of the country. In the neighbourhood of Kotta Bangoen, as well as at Tangarong and Moeara Kaman, Mr. Bock found traces of a former Hindoo occupation.

While at Kotta Bangoen, the Sultan and a numerous suite arrived, but Mr. Bock preferred to continue the journey alone, on account of the many occupations which an Indian monarch indulges in. In order to study the different wild tribes, he proceeded through the lake region. He was fortunate enough to meet the Tring Dyaks, the only cannibals in Borneo, with whose Rajah, Sibau Mobang, Mr. Bock spent a couple of days. This man is a savage of most forbidding appearance, extremely ugly: he told the traveller, in an easy way, that the brains and palms of the hands of men tasted delicious, whereas the shoulder part always had a bitter taste. After Mr. Bock had drawn his portrait, Sibau Mobang presented him, on his departure, with two human skulls, and with a shield ornamented all over, in a very ingenious way, with human hair. During the time Mr. Bock travelled in Koti, Sibau Mobang and his followers killed in one week—being out on a head-hunting excursion—not less than sixty people.

At Moeara Pahou, the last Malay village in the interior, Mr. Bock again met the Sultan and his suite, who had gathered together a number of Dyaks to escort the expedition through the most dangerous part of his territory. The journey was continued down the Moeara Pahou river, which close to Moeara Anang becomes very difficult to navigate. There are many rapids, over which the canoes had to be dragged by means of rattan ropes, the luggage and provisions having to be first discharged. At Moeara Anang the march through the great forest began, the most fatiguing and dangerous part of the journey. Here one of the Dyaks was murdered, and attempts were made to poison Mr. Bock and his followers. A path of the rudest description had first to be constructed by the natives, and, in order to cross the numerous small rivers and abysses, they had made bamboo bridges. Only those who have travelled in the tropics can form an idea of these elastic structures, more fit for an acrobat than an ordinary traveller. After four days' march from sunrise to sunset, the Benangan river was reached. By this and the Tewéh river, and down the great Barito, Mr. Bock and his party reached Banjermassin on December 31, two days before the Sultan and suite.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *On the North-East Passage.* *By* Lieutenant GEORGE T. TEMPLE, *R.N.*

The author sketched briefly the history of the North-East Passage since the ill-fated expedition of Sir Hugh Willoughby, showing how the way was gradually paved for the brilliant success of Baron Nordenskjöld, and recapitulated the advantages likely to accrue from the establishment of a regular trade between Europe and Siberia. He then gave an outline of Nordenskjöld's Arctic career up to 1876, and described the voyage of the *Vega* in some detail. The nature of the country and the manners and customs of the Tchuktches were also touched upon, and Nordenskjöld's summary of the immediate practical results of his enterprise was quoted. Referring to the various attempts which had been made to follow up the successful voyages of 1875 and 1876, the author mentioned that several foreign vessels, specially built for the purpose, were actively engaged at that moment, and that the steamer *Nordenskjöld* was attempting the North-East Passage in the inverse direction. In connection with this subject, Lieut. Temple remarked that the sailing directions for the coast of Norway, to which he alluded at the preceding year's meeting of the British Association at Sheffield, had now been published by the Admiralty, while some of the Norwegian charts were in course of preparation. It was trusted that, in spite of some apparently inevitable errors, the publication of this work, with the necessary charts, would fill up the gap which had hitherto existed for British navigators in the new commercial highway, and that British seamen would be better able to take their share in the establishment of a regular trade-route between Europe and the mighty rivers of northern Asia, by means of which the vast, but hitherto pent-up, wealth of Siberia would find a natural outlet to the great commercial centres of the civilised world. The discovery of the North-East Passage might, altogether, be regarded as the most completely successful Arctic voyage that had ever been made. The paper concluded with a warm tribute to the foresight, gallantry, and skill with which the enterprise had been conceived and carried out.

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2. *On an Examination of the Balearic Islands.* *By* Dr. PHENÉ, *F.S.A.*, *F.R.G.S.*

The author gave a general description of the several islands in the group, with the meaning of their appellations and the method of reaching them; following with a description of the energetic agricultural operations of the rural classes, and the nature of the soil, and a general view of the aspect of the country in each island.

In Minorca there are no guides, and the inhabitants of one end of the island seem to know nothing of the other, or of anything in it except in their own districts. Of the extraordinary remains in Minorca there is absolutely no historic information; the masonry indicates that they are Cyclopean of the oldest type, while that of the Nurhags of Sardinia, with which many suppose they agree, is not only in courses, but of wrought or well-trimmed stone. The grand feature of the latter also is wanting, viz., the spiral staircase or ramp, which is found also in the Brocs of Scotland. The plan of the grandest structure in Minorca is square at the base, and forms a pyramid of which there is no example in Sardinia.

There is historic reference to the Nurhags of Sardinia, and even to their builder, Iolaus, but the antiquity of the remains in Minorca is lost in the mist of ages, or referred to the time of the very oldest of the mythological deities, Saturn. The works of Iolaus in Sardinia are described in a way to prevent mistake, and they

are found to-day as then described. There are some portions of these Nurhags which appear of an older date, possibly the same as that of the towers in Minorca, as they are very rude, and from these Iolaus probably designed and improved and produced the present Nurhage, adding the staircase.

The remains in Minorca differ altogether from the Nurhags of Sardinia, by having, as a part of them, stone tables, said to be for sacrifice, and circles of monoliths, neither of which are found in Sardinia. If they existed previously, they were probably removed on the coming of Iolaus, and the new-comers introduced their own religion. Another special class of monuments in Minorca differs altogether from anything in Sardinia. These are vast ships built of stone of an immense age, as proved by their masonry. The monuments themselves, as shown by photographs, and compared with photographs of the earlier Cyclopean masonry of Greece and Samothrace, are found to be of the very earliest type, assimilating more to the most ancient circular structures in Etruria than any other remains.

Dr. Phené then described the architectural beauties of the city of Palma, his various journeys and researches, the mixture of races on the islands, and quoted the known classical references to these islands, remarking on the people, and their ancient and modern customs.

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3. *On a recent Examination of the Topography of the Troad. By* Dr. Phené, *F.S.A., F.R.G.S.*

The author stated that during several successive visits to the Plains of Troy, his attention had been drawn to the former course of the Scamander from the remains of irregularities in the surface which indicated a former defence by earthworks, and also a number of heaps of earth which he concluded indicated Trojan interments. The latter were on the heights, and the whole occupied the space between Hissarlik and Balidagh near Bunarhashi. His object in noticing these was to point out what appeared to him an omission by former explorers, as the line he indicated would be the natural line of defence of the Trojans, the Scamander forming a formidable frontier defence, which with a comparatively slight earthwork, to protect the defenders, would have prolonged the siege indefinitely.

From the heights at the rear of this defence, on which were the tumuli referred to, every operation of the Greeks could have been observed, and on them the large body of allies securely encamped, while the land also could have been tilled in security. Homer applied the term *'εριβώλαξ* (fertile-soiled) to Troy, by which he must have meant the part outside the walls.

This topography would establish and reconcile all conflicting views, as the site of Hissarlik would then become the place of the city or mart of Troy (evidently, from its geographical position, a place for interchange of commerce, and where the produce from the Caspian and Black Seas would meet that from Syria and Egypt), and Balidagh would be the citadel. Homer also applied the term *εὐρυάγυια* (broad-wayed) to Troy, to Mycene, and to Athens; and each of the two latter places had long, broad, and defended roads to their citadels, the one from Argos and Tiryus, the other from the Piræus and Phalerum. That Troy should be without such ways in face of this appellation given by Homer to it in common with other cities found to have them, seemed improbable, and such ways were in the other cases outside the walls, but not outside the external bulwarks attached to the city.

The small dimensions of the foundations at Balidagh, which are of a very careful construction, would be quite sufficient for Priam's Palace and the Scæan towers, though not for the great city; and the author attributed their present preservation to the unburnt bricks which formed the superstructure, precisely as in the case of Mantinea in Arcadia, which Pausanias states was built of such material, and which city Dr. Phené made a special journey to examine, in order to compare its foundations with those at Balidagh, which, being on the spurs of Mount Ida, must be the classical site, and, like the temple and palace at Ephesus, removed from the tumult of the commercial city. In support of this, it was pointed out

that all the tumuli outside the natural river-boundaries were by tradition Greek, while all those within, of which one end of the line of tumuli was at Balidagh and the other end at Hissarlik, were as distinctly recognised as Trojan. Such defences as he described on the Scamander were on the old course of that river, and were the usual defences of that age. Homer describes the Greeks erecting a breastwork of this sort to protect their fleet, and their making a ditch to supply the place of the river, and Herodotus (Book 9, chap. 97) gives a similar description of Persian work at Mycalé. If such a work existed it was no doubt an original defence and not made during the siege, which latter caused the Greek one to be specially noticed. The position of the Scæan gate as suggested was shown to be exactly that of the Cyclopean bridge and gate leading from Mycenæ to the plain of Argos on the way to that city, and the length of the broadways of Athens and of Mycenæ agreed almost minutely with the distance from Hissarlik to Balidagh.

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4. *A Visit to the Galapagos Islands in H.M.S. 'Triumph,'* 1880. *By* Captain Markham.

Captain Markham gives an account of a visit he paid to the Galapagos Islands on board H.M.S. *Triumph,* in the beginning of the present year. The Admiralty chart, compiled from a rough survey made nearly half a century ago, is not very accurate, so that it was not safe for a large ironclad like the *Triumph* to extend the cruise in the numerous channels between the islands. Her visit was, therefore, confined to Post Office Bay in Charles Island, and the paper records the observations that were made during several inland excursions.

The Galapagos Islands, being 600 miles from any other land, have a peculiar fauna, and Captain Markham devoted all the time at his command to the collection of birds, skins, insects, and shells. These specimens have been placed in the hands of Mr. Salvin, and it is anticipated that they will form an addition to our knowledge of the natural history of this isolated archipelago.

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5. *On a visit to Skyring Water, Straits of Magellan.* *By* R. W. Coppinger.

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6. *Notes on the Dara Nur, Northern Afghanistan, and its Inhabitants.* *By* Lieut.-Col. H. C. B. Tanner.

[N.B.—Notices of some of the above-mentioned Papers in this Section, incapable of abstraction, will be found in the number for October, 1880, of the 'Proceedings of the Royal Geographical Society.']

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—GEORGE WOODYATT HASTINGS, M.P.

THURSDAY, AUGUST 26.

The following Reports and Papers were read:—

1. *Report of the Committee appointed for the purpose of reporting whether it is important that H.M. Inspectors of Elementary Schools should be appointed with reference to their ability for examining in the Scientific Specific Subjects of the Code in addition to other matters.* See Reports, p. 219.

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2. *Report of the Committee for inquiring into the present appropriation of Wages and Sources of Income, and considering how far it is consonant with the Economic Progress of the People of the United Kingdom.* See Reports, p. 318.

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3. *Vital and other Statistics applicable to Musicians.* By P. M. TAIT, *F.S.S., F.R.G.S., &c.*

The memoir commences with a rapid sketch of the origin and history of music, musicians, and musical instruments. Mahalaleel, the fourth in descent from Adam, was the first vocalist, and Tubal-cain, fifth lineal descendant from Cain, the first instrumentalist. Reference is also made to previous inquiries into the mortality of musicians, and notice is taken of a paper by Dr. William Augustus Guy, F.R.S., read to the Statistical Society in 1859, when actors, vocalists, and musicians were incidentally brought for the first time under observation. The data covered by the present paper are obtained more immediately from Messrs. Cocks & Co.'s 'Dictionary of Musicians' corrected by the more elaborate work of Dr. Grove, and other records. The records include 736 persons, of whom 697 are males, and 39 females, 458 being dead and 278 alive at the present time. The data thus comprise an aggregate of 32,925·5 years of life. The mortality disclosed is apparently considerably more favourable than that which obtains amongst other classes. There is a table comparing the mortality of musicians with that which obtains amongst the males of England and Wales, the peerage, government annuitants, and certain other classes. The deaths amongst musicians at ages from 15 to 45 are apparently considerably less than those which occur amongst any other class of society. There is no sufficient reason to account for this disparity so vastly in favour of musicians; and it can only be explained by supposing that in the Dictionary a number of musicians do not come under observation at the earlier ages; the deaths in fact having happened early, they do not come under review at all. From ages 46 to 50 the results are still in favour of musicians, and also from 51 to 55. From 56 to 60 the deaths are very much the same as those

observed to occur amongst the whole population of males in England and Wales. From 61 to 65 they are apparently slightly less, and also slightly less from 66 to the extremity of life.

Confining the observations to the mortality per cent. amongst the deceased lives only, the results are considerably in excess of those applicable to the whole 736 persons. Probably the literal truth lies between the columns indicating the results in each case.

The paper passes on to discuss the influence of heredity in the production of musicians, and this is manifest to a very great extent. Thus, in the cases of Bach, Beethoven, Bellini, Cherubini, Gounod, Haydn, and others, the influence of heredity is apparent.

A curious circumstance comes out in the extreme paucity of female composers. Amongst the number of female singers the great names of Alboni, Catalani, Grisi, Lind, Lucca, Nilsson, Patti, Sontag, and Tietjens are included, while only four are even indicated as composers. Of these the most remarkable in point of versatility is undoubtedly Madame Viardot Garcia, born in Paris in 1821, but of direct Spanish extraction, and sister of the famous Malibran, whose family for a hundred years has been musical. And here it may be stated that the ages of living *prime donne* are given in the records with an almost ruthless fidelity. But it is not of course sought to enlarge on that delicate point.

An attempt is made to indicate the nationality and race of musicians, by classifying the whole number under different nationalities, and also by classifying the published musical dictionaries up to the present time. 35 per cent. of the whole number of musicians are from Germany; 15 per cent. from Italy; 11 per cent. from France; 10 per cent. from Austria-Hungary, of whom the great majority are German-speaking; and 18 per cent. from Great Britain and Ireland. As to dictionaries, according to Grove and others, from 30 to 40 have been published up to the present time. 38 per cent. are in German, 24 per cent. in French, and 15 per cent. in English, while only about 6 per cent. are Italian. The apparent superiority of England to Italy and France in the production of musicians and musical dictionaries is explained. The general conclusion under this particular head is, that the ranks of modern musicians have been recruited mainly from the German or Teutonic stock, that portion of the Japetic or Indo-European branch of the human family whose descendants, according to Pritchard and other authorities, reached Europe by way of Turkestan, the Euxine, and the mouths of the Danube; that, next to the Germanic, come the Latin races; and that, finally, we have the Celts and the Sclaves, each of which race has contributed, though in considerably diminished numbers, its quota to the ranks of musicians.

The general result of the whole investigation is, that while the tables indicating the mortality of musicians are interesting as a guide to information on the subject, the facts under observation are too few to justify absolute conclusions as to the mortality at the earlier ages, or to enable the tables to be used without other aids for the computation of financial values applicable to musicians. It is clear, however, that musicians in many instances live to a great age. Thus among famous deceased octogenarians we find the illustrious names of Auber, 87; our own Braham, 82; Cherubini, 82; and Cramer, 87; while Sir George Smart lived to 91; Sir John Goss having only recently died at 80. There are about half a dozen living octogenarian musicians of note, chiefly resident in Germany. On the other hand, among musicians who died comparatively young we find the names of Beethoven, who died at 57; Bellini at 34; Bizet at 37; Chopin at 40; Cimorosa at 52; Fanny Hensel at 41; Herold at 42; Mendelssohn, 38; Schubert at 31; Schumann at 46; Thalberg at 59; Vincent Wallace at 47; and Weber at 46.

An attempt is made to classify musicians according to the specialty of each. It is found that 27 per cent. of the whole number are returned in the records as composers pure and simple; 37 per cent. as composers and instrumentalists; while about 7 per cent. are vocalists pure and simple.

The memoir has a very wide range, and a great number of authorities are quoted, from the 'Rig Veda' downwards.

4. *Agricultural Statistics and the Land Question.* By Wm. Botly, *M.R.A.S.*

This paper was a continuation of the Agricultural Statistics to the present time, in a tabular form, strongly advising their continuance and early publication.

In the second part it gave the imports of cereals, cattle, sheep, and swine, meat, &c.; their prices and amount in value

Thirdly, the number of owners of land in Great Britain; also, separately, that of Ireland, in a table of from one acre up to 100,000 acres, with the respective rentals.

The concluding portion of the paper argued for some considerable alterations in our Land Laws, supporting this view of the question by extracts from the opinions of the present and late Lord Chancellors, as well as other eminent statesmen; and finally, that to improve agriculture and to bring men of greater capital, skill, and enterprise into the business of farming, there must be security of tenure and compensation for all unexhausted improvements.

It was shown that in the past year our imports of wheat and various other cereals, with meat, amounted in the aggregate to 140,000,000 cwts., exclusive of butter, cheese, eggs, &c., &c.

FRIDAY, AUGUST 27.

The following Reports and Papers were read:—

1. *Report of the Committee on the German and other Systems of Teaching the Deaf to Speak.*—See Reports, p. 216.

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2. *On the recent Revival in Trade.* By Stephen Bourne, *F.S.S.* See Reports, p. 436.

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3. *On Admiralty Monies and Accounts.* By Frank P. Fellows, *F.S.S.*, *F.S.A.*

This was the continuation of a paper read at the Statistical Society, London, 'On our National Parliamentary Accounts, &c.'

In that paper it was shown that—' the average yearly expenditure for ten years previous to 1869, was 11,587,041*l.*, and for the five years, 1869–70 to 1873-4 (taking the estimates for the last year) was only 9,785,915*l.*, and that " these great results had been brought about by a variety of means, not the least efficient being the check our improved accounts have given us over expenditure, or what is still more important, over the final results of expenditure." '

The latter point the present paper illustrated more in detail.

In 1861, a Royal Commission was appointed to inquire and report upon the management and control of H.M.'s Dockyards.

They examined seventy witnesses, all of whom were, or had been, officials, except two—amongst them, Sir James Graham, who stated as follows: 'It is quite competent to frame a form of accounts, and that the evil would be remedied in six months. The accounts will be imperfect unless every kind of charge a shipowner would bring to book is carried to account. An account misrepresenting values is infinitely more dangerous than no account at all. An imperfect account, in my humble judgment, is infinitely worse than none.'

Sir John Pakington before the same Commission said: ' If the accounts were kept so as to show the exact cost of ships, a competition in economy would be

established between the different Yards, which would be of great benefit to Her Majesty's service.'

They reported finally:

'We regret to state that in our opinion the control and management of the Dockyards is inefficient, and that the inefficiency may be attributed to the following causes . . . . . . 4. The absence of any means, both now and in times past, of effectually checking expenditure, from the want of accurate accounts.'

The paper proceeded:

In 1864, in connection with Mr. Seely, the Member for Lincoln, I undertook a systematic and detailed examination of the finance and other accounts of Government, more especially those of the Admiralty.

The result of these investigations, brought forward from time to time in the House, clearly showed that up to and after this period to 1868, the evils complained of by the Royal Commission of 1861 had not been remedied.

I give a few examples extracted by me from Admiralty accounts, and given by Mr. Seely at various times in the House, which, I think, clearly prove the evils still existed.

From 1862–3 to 1864–5 in one year or two years—where expenditure overlaps:—

Ten ships cost *in repairs, &c.* (one repair in each case) in one financial year, or two such years when the expenditure overlaps the end of one and runs into another year: viz. the *Highflyer, Niger, Malacca, Cruiser, Sparrowhawk, Pearl, Simoom, Lyra, Oberon,* and *Torch*	£450,810
And ten similar ships bought new, completely built, fitted, and equipped, at the rate of 33*l.* per ton, and 55*l.* per horse-power would have cost only	449,906
Five others, *Salamander, Barracouta, Falcon, Sharpshooter,* and *Wasp* cost in repairs	163,584
Five new, completely built, fitted, and equipped would cost at same rate as above	183,797
Or these fifteen ships cost in repairs	614,394
Fifteen similar new ships at 33*l.* per ton, and 55*l.* per horse-power would have cost, completely built, fitted, and equipped	633,703

It is a rough rule with shipbuilders taking a number of ships during a series of years, that old repaired ships after repair are worth about half as much as similar ships. On this basis,

These fifteen ships cost in repair, &c. (one repair) . . .	£614,394
The value of these fifteen ships after repair would be only .	316,857
And would show a loss thus of	297,537
Say, in round numbers	300,000

Details of fourteen other ships were given, showing great excess cost in repairs, and the conclusion arrived at was that on these twenty-nine ships' repairs (one repair in each case, years 1862–3 to 1864–5), the expenditure they incurred was 500,000*l.* more than the ships were worth after such repairs had been executed.

Numerous details were then given showing like results in the 160 manufactories, factories, and shops of H.M.'s Dockyards, as for instance, numerous boats repaired at a cost sometimes greater than double that at which similar new boats completely built and fitted could have been made or bought.

Cases were quoted of forgings, blanks, and numerous classes of articles that cost 20, 50, and 100 per cent. more at the manufactory at one dockyard than similar articles at another, and even the lowest cost was in many instances much greater than the outside market cost of similar productions.

As to the total cost of the 160 manufactories of the several dockyards, figures were given showing the average yearly cost from 1861 to 1867-8 (7 years) had been about .	£1,500,000
That in 1868-9, when Mr. Seely's Committee had reported and approved the adoption of the author's plans to give complete control over these great establishments, the total cost was reduced to	1,116,014
And from 1869-70 to 1878, the yearly cost had been about	800,000
Or a reduction yearly of	700,000

A considerable proportion of this was shown to be distinctly attributed to the reforms introduced, by which excess cost at any yard was clearly shown in detail of 'labour,' 'material,' and 'general expenditure,' and extravagant yards and manufactories, and factories called to account, and for the future obviated.

The system introduced into the Admiralty by the author was described in detail, by which the three previously apparently unconnected sets of accounts—1. Navy Estimates and Parliamentary Finance Accounts; 2. Ship-building, Repairing and Dockyard Expense Accounts; 3. Manufacturing, Factory, and Engineering Establishment Accounts; were connected and made into one great account through the instrumentality of his Retabulations of the Navy Estimates, Appropriation Accounts, and surpluses and defects on the grants, and by modifications of the ships' and manufacturing accounts.

It was explained fully how, by means of the author's scheme of separate rate-book of prices for each manufactory and dockyard; by treating each as a separate establishment also with respect to the indirect and incidental expenditure, in accordance with his proposals, great economical results had been obtained, by enabling comparisons of cost in detail of labour, materials, and general expenditure to be systematically and correctly made, and excess cost detected and checked.

This was largely supplemented and aided by his annual lists of differences in the cost of similar manufactures—at the 160 manufactories, factories, &c., of H.M.'s several dockyards, by which every manufactory and dockyard had to account for all such excess cost in the detail stated; of 'labour,' 'material' and 'general expenditure,' and it was shown that this had been done whilst, at the same time, a great saving in clerical labour had been effected.

Figures were given to show that about 5,000,000*l.* of yearly expenditure in detail of shipbuilding and manufactory had thus been brought under strict control, and that the saving thus—through unwise expenditure being prevented, and due economy in material and labour being instituted—was about 500,000*l.* yearly.

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4. *Report of the Anthropometric Committee.* See Reports, p. 120.

SATURDAY, AUGUST 28.

The Section did not meet.

MONDAY, AUGUST 30.

The PRESIDENT delivered an Address.

The following Papers were read:—

1. *Protection in the United States and its Lessons. By* GEORGE BADEN-POWELL, *M.A., F.R.A.S., F.S.S.*

When the question of Free Trade is broached, the rejoinder is, 'Why, then, do the United States flourish so with their Protection?' If we examine the facts of the case, we shall find that in the United States prosperity exists in spite of and not because of Protection, and that Protection has hampered and not assisted the development of native manufactures in the United States.

Firstly. Protection cannot seriously affect the prosperity of the United States, because the import trade is comparatively insignificant.

Also. The United States is an undeveloped country. It not only feeds itself, but half its exports are food. This is a source of wealth unaffected by Protection.

[This food-producing will only affect the English market in a gradually decreasing ratio: as population increases in the States it rapidly raises the cost of growing food; it rapidly raises the cost of carriage. The margin of profit is small now, and will eventually be destroyed by this inevitable growth of population. The British farmer by the end of the century will have little American competition to face.]

Also. Absolute Free Trade exists within the United States. And, considering that this Free Trade covers an area the size of Europe, and at least equal in fertility and resources, we see it is the one great factor in the prosperity of the United States, and one that successfully resists the evil effects of a high tariff towards outsiders.

Secondly. Protection has hampered and not developed manufactures.

(1) It is true that the *amount of virgin soil* perpetually being brought under cultivation relieves manufactures in bad times; but even so, distress in the 'artificial' manufacturing districts of the States is always greater than in the 'natural' districts in England.

But this wealth of virgin resources not only supplies manufacturers with abundant raw material, but also with a class of wealthy local consumers. This wealth at once nourishes the body of manufacturers and conceals its diseased condition.

(2) We find that the protected manufacturers fail to monopolise the *home market.* The high prices, consequent on Protection, enable foreign manufacturers to pay the high duties, and provide them with means to pierce the barrier set up. The increase of population would naturally start manufactures, but is prevented from so doing by this high tariff, which invites and enables foreigners to supply the local market.

(3) American manufacturers do not export. What little they sell in *foreign markets* is mainly what results from bad times in America. Stocks on hand that then find no sale in the States are supplemented by stocks created by manufacturers because of the abnormally low prices of labour in depressed circumstances.

(4) Then, too, manufacturers are hampered on all sides by the high prices of all they use or consume. They cannot produce cheaply, and so fail to compete in foreign markets. Protection stifles their powers of competing. It hampers and does not foster native manufacturing enterprise.

Thirdly. It may be asked, Why do the people of the United States, with all their acknowledged intelligence and cleverness, put up with such things?

1. One reason is, they are but little affected directly by Protection. They are occupied almost exclusively with opening up vast virgin resources. The wealth that results is so great that they pay little heed to the loss imposed on them by Protection.

2. Another plea, worked by the few that profit by Protection, acts as a great

gloss over these evils. It is that of raising revenue to carry on government. While the West is yet to be opened up, Americans turn nearly all their attention westwards. When the work is nearer its end they will look back, turn more attention eastwards, and discover that a low tariff yields as much revenue as a high tariff.

In conclusion. The lessons we learn from this instance are, generally, that Protection has acted as a drag on the prosperity of the United States, and hampered and not fostered the development of native manufactures; and especially that American competition in the English food market will now gradually dwindle.

It only remains to point out that as the United States become peopled up and fully developed more heed will be paid to external policies; and the interests that now keep alive the Protection that hampers them will sink before the assertion of wider and more popular interests.

The spirit and acts of this age are all in favour of Free Trade. Protection is a mere protest of a state of things that is passing away.

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2. *On the Preservation of Fish and preventing the Pollution of Rivers. By* Lieut.-General Sir James E. Alexander, *K.C.B.*, *K.C.L.S.*, *F.R.S.E.*

Allusion is made to the neglect of our rivers in many parts of the United Kingdom, and the prevalence of pollution from towns and public works. Salmon, it is stated, is generally so dear that the poor are deprived of its use. The town of Stirling, in Scotland, has a rent of £1,000 a year from its salmon fishery; but that will cease if the town sewage, gas works, paraffin works, &c., continue unchecked to be discharged into the Forth. A better state of things is reported from Callander and Dollar, where the sewage is prevented from polluting the streams. Heavy grass crops, beetroot, &c., are produced by the Edinburgh sewage distributed over the Craigentinny meadows. What occurs on the border river, the Tweed—overfished and polluted. A more stringent Act of Parliament is suggested, to deal with river pollution and the preservation and increase of fish.

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3. *On the required Amendment in the Marriage Laws of the United Kingdom. By the* Rev. Daniel Ace, *D.D.*, *F.R.A.S.*

The desirableness of uniformity in these laws was shown from three gross cases adduced. Whilst marriage is regarded as a civil contract, inducing a civil status, conferring the same rights and entailing the same obligations upon the persons entering into the said contract, the general feeling in the United Kingdom is in favour of superadding to this important contract the sanction of religion.

The matrimonial proceedings of the ceremony of marriage differ in the three kingdoms: the validity of the marriage solemnised in one of those kingdoms may be rendered nugatory in the other by some legal technicality. The effects of such diversity have been designated by Lord Chancellor Selborne as 'scandalous to a civilised country.'

The cases adduced, verifying the epithet, as to their effects, of the Lord Chancellor, were—

1. The Queen *v.* Millis, 1843, 1844.
2. Beamish *v.* Beamish, 1861; and
3. Yelverton *v.* Yelverton or Longworth, 1864, 1865.

The first, a case of bigamy, The Queen *v.* Millis.

In 1829, George Millis was married to Esther Graham, according to the rites of the Presbyterians, by an Irish Presbyterian minister, in Ireland; and in 1836, whilst Esther Graham remained alive, George Millis married, at Stoke, Devonshire, Jane Kennedy, by an English priest in holy orders. In 1842, George Millis was, at the Spring Assizes for Antrim, found guilty of bigamy on the aforesaid facts. A legal argument was raised in the Court of Queen's Bench, Ireland, and ultimately carried to the House of Lords, whether the indictment for bigamy could legally be sustained. The decision of the Appellate Court of the House of Lords quashed the indictment for bigamy, and set aside the first marriage of George Millis, on the principle involved in an ancient canon of the Church of England, viz., that of Arch-

bishop Lanfranc, at a Council held at Winchester, A.D. 1076, 'that no marriage is held valid, unless by an express statute, without the benediction of a priest in holy orders.' The late eminent and sagacious Premier, Sir Robert Peel, soon corrected this anomaly, affecting the validity of Presbyterian marriages in Ireland, by *three* statutes immediately enacted by the Legislature:

(1) 5 & 6 Vict. c. 113.
(2) 6 & 7 Vict. c. 39, A.D. 1843.
(3) 7 & 8 Vict. c. 81, A.D. 1844.

2. Beamish *v.* Beamish.

This was a case of an episcopally ordained clergyman in Ireland, who himself exclusively officiated at the marriage of himself to a lady, and consequently such marriage was rendered invalid, as the House of Lords decreed that the presence of another person or priest was requisite, according to law, in the case of the clergy as well as the laity, to receive the mutual consent of the contracting parties, and declare them to have become man and wife, these being the essential conditions of *legal* marriage.

3. Yelverton *v.* Yelverton or Longworth.

This case is the greatest blot upon our jurisprudence in modern times. A gentleman in Scotland went through a ceremony with a lady, which the Court of Session declared to be a valid marriage. Subsequently, the same affianced parties went through a ceremony before a Romish priest in Ireland, which, in the opinion of the Irish Court of Queen's Bench, constituted a valid marriage in that kingdom of Ireland. But on an appeal to the House of Lords, by a conflict of legal opinion (Lords Brougham and Westbury holding the parties legally married), the House of Lords decreed both marriage ceremonies (the one in Scotland and the other in Ireland) to be null and void.

Such samples of the conflict of marriage laws in the three kingdoms must be productive of an immense amount of practical hardship, patent injustice, and wanton cruelty. These sad judicial results led to the institution of a Royal Commission to make public inquiry whether the marriage laws could be assimilated. For three years, from 1865 to 1868, the Royal Commissioners pursued their investigations, and examined some very learned persons. At length they made their report, with divers recommendations. Since that period nothing has been done to remedy the crying grievances inflicted by a conflict of national laws; and it must be a matter of regret, if not of reproach, that no action has been taken by the responsible advisers of the Crown that the holy estate of matrimony may be rescued from flagrant injustice. The gist of various recommendations contained in the said report of the Commissioners involves the following considerations:—

That the whole of the enactments respecting marriages be consolidated in a single statute; that all existing statutes and ordinances of the United Kingdom on marriages (involving as a *sequitur* the repeal of the odious Irish Marriage Act, the 19 Geo. II. c. 13, and other penal Acts) should absolutely be repealed. The author of this paper would venture to add, 'all canons relating to marriage resting on the authority of statute law, by the 25 Henry VIII. c. 19;' great care being observed that by such repeal no canon on marriage expressly or virtually repealed by former legislation be thereby revived. Also, it is recommended that all stamp duties on matrimonial documents be abolished; and further, that marriage fees, so far as practicable, should no longer be exacted.

Again, *inter alia*, it is also recommended that all licences and banns for marriage should be superseded by a statutory declaration, made before an authorised and legally recognised minister of religion, by whom the affianced parties desire their marriage to be recognised; and that such a minister or official should be empowered legally to receive such a declaration, and to exact its correctness, with the same penalty annexed for falsehood and fraud as that of the penalty for perjury; also, that the certainty of marriage should be legally rendered unequivocal. But reasonable time and effective means should be supplied to interested parties to prevent clandestine, hasty, and improvident marriages.

Moreover, parties of mature age, of reputation and of status, well known to the respective minister of religion or civil officer, desiring to facilitate their prospective

marriage, should not be required to wait by giving fifteen days' notice, but a licence should at once be granted to consummate their wishes for the immediate solemnisation of their marriage contract; the same facilities being rendered to the poor as to the rich, as 'marriage is honourable to all.'

The publication of banns, it is admitted, is of great antiquity. We have traces of or reference to it in the early part of the second century, in the treatises of the Fathers, Ignatius and Tertullian. But although this ancient mode of notice of marriage, viz., the publication of banns, has existed for more than eight hundred years in this country, the publication of them at this period of time is quite unsatisfactory.

What useful purpose can now be served by them, let anyone attest who has attended divine service at Manchester Cathedral, or any parish church in a densely populated locality. That such publication of intended marriages by banns is utterly impracticable the late Registrar-General has proved by recording his decided and valuable opinion, and to this verdict we respectfully submit. Every useful purpose would be secured by the mere fact of a registered notice from the contracting parties, accompanied with a true declaration of facts, exacted upon pain of the penalties of perjury, that no legal impediment existed. Yet those who prefer the publication of their banns of marriage may be permitted to enjoy this luxury; but in no case should the publication of banns be required as a condition either of the lawfulness or the regularity of marriage. All preliminary requirements should be regarded as directory, and none of them as essential to the validity of marriage, or in any wise to invalidate it.

No minister of religion or civil officer should arbitrarily, or without a sufficient legal reason, interpose impediments to the reception of notices of marriage, or to the granting certificates thereof. On the other hand, all undue or illegal facilities to marriage should be severely punished.

All penalties of felony assigned to ministers or civil officers in dereliction of their duties should be reduced to those of misdemeanour. A certificate of notice by any beneficed clergyman should be a sufficient authority for parties to be married in another parish, if they respectively desire it. No clergyman should be relieved from the obligation imposed on him by the law or sect to which he belongs; but the time and place of marriage are matters of which the State should take no cognizance; canonical hours of marriage, having reference to the sacrament of the mass, in which Protestants are not interested, should by Act of Parliament be abolished. As a matter of history, we know that marriage in churches was not established till the twelfth century, by the ordinance of Pope Innocent III. A.D. 1200.

Consensual or pre-contract marriages, *per verba de præsenti, et per verba de futuro, subsequente copulâ*, though agreeable to the civil law (*consensus facit matrimonium*), must not be revived in England, now abolished by stat. 4 Geo. IV. c. 76, A.D. 1823. In Scotland they are now legalised, as well as marriages by repute; but marriages legalised in that kingdom, and ratified by the decrees or decision of Scotch Courts, should be recognised as being legal to the status of the said parties in England.

Let Mr. Monsel's Act (26 & 27 Vict. c. 90), with respect to the registration of Roman Catholic marriages in Ireland, instead of being directory, be rendered, by Act of Parliament, imperative.

The Canon Law of Europe does not—it never did—form a part of the Law of England. It does as to marriage in Scotland. But the laws of the Council of Trent were never acknowledged in England. But latterly, in the formerly excepted Provinces of Ireland, the canons of the Council of Trent are revived. Hence arise the dire conflict of the laws of marriage in the three kingdoms in the administration of justice, and the cancelling in England of one of the most important contracts of all social relations which in one of the two other sister kingdoms may be held valid. And all this through the glorious uncertainty of the laws of marriage, as appears in grievous suits of litigation.

But Cicero has written:

Indignum est in civitate, quæ legibus contineatur, discedi a legibus.

Such are the arguments of the author of this paper for the immediate interposition of the Legislature, and for the strong support of the Government, to sweep away a heterogeneous congeries of at least twenty-seven Acts of Parliament and other diverse ordinances, and to enact a general marriage law for the three kingdoms, admitting and legalising the peculiarities of each, but securing for all the certainty of a valid and indisputable marriage, for the legitimacy and peace of families, and for the maintenance of the rights and preservation of the property of the married pair. In doing this let every care be taken to prevent the scandals which occurred through the unscrupulous conduct of unworthy clergymen prior to Lord Hardwicke's Act (26 Geo. II. c. 13), now happily repealed; but its best provisions are now incorporated in the English Marriage Acts. Fox and Mackintosh unsparingly condemned this Act for its tyranny. But the doctrine of *non fieri debet, factum valeat* admits of some state regulation. That Fleet Prison and May Fair marriages were a scandal to a civilised and Christian country, those acquainted with history will readily admit. But the greater scandal arising from a conflict of marriage laws, uncertain in their operation, remains.

To remedy this scandalous contravention of the marriage laws, the nation calls aloud. Marriage, says Lord Stowell, is the parent of civil society; but, more than this, it is the basis of social science, and of *sound morals*; it is the purest source of domestic affection and of angelic virtue.

Lex est ratio summa, insita in naturâ, quæ jubet, ea, quæ facienda sunt, prohibetque contraria (Cicero, 'De Legibus,' lib. i. chap. vi. 18).

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4. *On Diminishing Annuities—a Neo-Philosophy in Lending Funds. By* Frederick N. Newcome.

The assertion that a debt of any magnitude can be actually redeemed within a limited period at a less expenditure than is involved in the payment of interest on an interminable one, during the same number of years, may appear startling, even in this era of remarkable surprises. When speaking of redemption, I include the payment of regular dividends and the reimbursement of the principal. Antagonistic to common sense as this statement may appear, its feasibility and practicability can be readily demonstrated. Such is the miraculous power of compound interest that when once a departure is taken from the laws governing the three recognised financial philosophies, the apparent paradox involved in this equation is easily explained away. To enounce that a debt can be repaid with less than the cost of interest sounds an extreme paralogism; but it is nevertheless true, and must be admitted as a neo-philosophy into the world of economic science. The discovery was made by myself about twelve months ago, when elaborating a plan of redemption permitting of a frequent reduction in the annual charge. On comparing it with the cost of annuities for the same number of years, it was at once visible that some fresh and important phenomena had to be considered—a new and potent power was at work somewhere—a vast economy had been effected! but how? There stood the figures bold enough, 3,508,054*l.*, to liquidate a six per cent. loan of 1,000,000*l.* in sixty-two years. There they were, correct and indisputable, while it was equally clear that an interminable debt must entail, for interest alone, 60,000*l.* paid for sixty-two years, or 3,720,000*l.*, and the debt of 1,000,000*l.* would still be owing. A gross saving had resulted of 211,946*l.*, plus the capital, or 1,211,946*l.*, in all. What is of more importance to science, it was clear that when the gross cost by this new principle is compared with that of annuities or debentures expiring in the same number of years, there must be a net saving of 315,103*l.* on the cheapest methods of redemption hitherto known. It is at once cognoscible that the omnipotent power of compound interest is at work in an intensified form. Those who have acquaintance with actuarial calculations are constantly reminded of its illimitable potency—a potency augmenting, we may almost say, by involution, as the rate of interest increases and the duration extends. Having stated that the action of compound interest is the efficient and acting cause producing the phenomena, it might *primâ facie* be concluded that, to secure the end in view, a great present sacrifice is inevitable. But such is not the case; a very small one is sufficient, but,

of course, with each augmentation to the first-created sinking fund, a vast addition to the ultimate saving will accrue. In the instance cited above the original fund is a half per cent. or 5,000*l.* per million. To redeem that amount of six per cent. debt, the annuity required, whether applied by repurchase in the open market, by grant of diminishing annuities, or by a checked cumulative sinking fund, is—

First 10 years	£65,000	Fifth 10 years	£53,000
Second 10 „	62,000	Sixth 10 „	50,000
Third 10 „	59,000	Last 2 „	30,000
Fourth 10 „	56,000		

It will be advisable here to say a few words respecting the advantages and demerits of the three principles of redemption enumerated above.

Section 1.—*Repurchase.*

In repaying the national debt of Great Britain, or any other country, on the system now promulgated, no alteration of the existing fiscal system need ensue, provided the stock was periodically purchased for cancellation. Government would merely have to publish a plan of redemption, detailing the amount of stock to be cancelled each three or six months. When the redemptions were effected below par the surplus saving could be placed to a fund, and accumulated for the purpose of defraying the losses incurred by cancellations above par.

Section 2.—*Diminishing Annuities.*

In no form whatever can annuities take more than a secondary part as a medium for reducing debt. By entailing the loss of capital, a limit is placed on their general use. Mr. M'Culloch justly described them as radically objectionable, and every sensible man must coincide in that opinion. Each dividend diminishes the selling value of the annuity. Consequently what we may designate the 'capital' is constantly decreasing, until at last, nothing remains. As a means of reducing debt they are efficacious, but I deny that they are the cheapest or best method.

Compared with ordinary annuities, I have little hesitation in saying that diminishing annuities are, from the borrower's point of view, vastly superior; thus in the loan under consideration, by the old system 10,000 annuities of 6*l.* 3*s.* 4*d.* each would be issued, whereas by my newly discovered system they would be for the first decade 6*l.* 10*s.* each, second 6*l.* 4*s.*, third 5*l.* 18*s.*, fourth 5*l.* 12*s.*, fifth 5*l.* 6*s.*, and sixth 5*l.* each, while for the last two years 3*l.* would be paid each annuitant.

Or, to bring the subject more home to ourselves, the Government of Great Britain could issue 3 per cent. annuities of 3*l.* 10*s.* each for forty years, and 2*l.* 10*s.* each for the remaining forty-seven years; or again, 3*l.* 10*s.* each for thirty years, 3*l.* each for the next thirty years, and 2*l.* 10*s.* each for the last twenty-four years. There is absolutely no limit to the number of possible variations. This invention opens up a new and illimitable field in the domain of financial economy. An endless scope exists for the development of fresh schemes. In compiling an ordinary table of annuities, the value of money at compound interest is calculated; so in these diminishing annuities is this element likewise taken into account, and although the borrower is enabled to repay the loan at a greatly decreased cost, the lender obtains the value of his money by receiving 6*l.* 10*s.* for the first decade, and 6*l.* 4*s.* for the next, instead of 6*l.* 3*s.* 4*d.* per annum throughout. The value of the extra 6*s.* 8*d.* for the first period and 8*d.* for the second, when computed at compound interest, exactly compensates for the subsequent losses of 5*s.* 4*d.*, 11*s.* 4*d.*, 17*s.* 4*d.*, and 1*l.* 3*s.* 4*d.* during each of the next decennial periods, and of 3*l.* 3*s.* 4*d.* for the last two years.

Section 3.—*Terminable Debentures.*

Terminable debentures, repayable by fixed quarterly drawings, are an even cheaper method of redeeming debts than annuities. This is a first but small advantage when compared with others I shall enumerate. I classify them as under:—

1. Absolute fairness, the debt being necessarily repaid with 100*l*. for each such sum nominally borrowed; while the element of chance introduced by the drawings renders it absolutely impossible to favour the redemption of any particular bonds.

2. The investment must be returned at some uncertain, but not distant, date, and until its repayment regular interest is received. It is on this question—the preservation of wealth—that this system so immensely preponderates over its rival, the terminable annuity. The one promotes extravagance and injures posterity; the other inculcates thrift, and safeguards the rights of future generations.

3. The principle is susceptible of unlimited modification, the magnitude or smallness of the debt being of no account one way or the other, except that small sums are always more readily handled.

4. The sinking fund is absolutely inviolable, and owing to this characteristic may commence at a fractional sum; $\frac{1}{10000}$th part of the principal will redeem a 10 per cent. debt in seventy-three years; while $\frac{1}{1000}$th part will suffice to repay a 5 per cent. debt in eighty-one years. The attention of statesmen and economists should be more earnestly directed to the various phases of this truly grand financial evolution. In England especially it has been neglected for the study of antiquated and malevolent schemes, and the outcome is that, having paid the debt six or seven times over, we still owe 780 millions. Large as the debt undoubtedly is, its liquidation would not be difficult to a nation of such vast resources as England, providing that we at once discard the present amusement of 'playing at repayment,' and adopt, in lieu thereof, a grand and invincible principle. We can well afford the luxury, as by so doing taxation is instantaneously reducible by a couple of millions sterling, while the ultimate extinction of the debt is uncontrollably assured.

5. By periodically checking the cumulative sinking fund provision can be made for a rapid reduction in taxation.

In the above epitomised summary of the salient features of the leading financial principles, it will have been observed that I lean strongly to the last, although the novel scheme of liquidation I now promulgate is equally applicable, by either of the three. Perhaps the most valuable lessons may be taught the inhabitants of Great Britain, if I address my remarks almost exclusively to the subject of our stupendous encumbrance.

Space prevents more than a summary being given of the periodical payments required, by one or two plans. I exhibit the amounts, first at per million of debt; secondly, for the funded debt; and, thirdly, for the total of the gross debts.

SUMMARY.

Period	Term	Initiatory Sinking Fund per million	Amount of each Annuity	Annual charge on £1,000,000	Annual charge on £710,000,000	Annual charge on £780,000,000
			Plan No. 1.			
		£	£ s. d.	£ about	£ about	£ about
1	10 years	3,500	3 7 0	33,500	23,785,000	26,130,000
2	10 ,,	4,200	3 6 0	33,000	23,430,000	25,740,000
3	10 ,,	5,100	3 5 0	32,500	23,075,000	25,350,000
4	10 ,,	6,400	3 4 0	32,000	22,720,000	24,960,000
5	10 ,,	7,600	3 2 0	31,000	22,010,000	24,180,000
6	5 ,,	9,200	3 0 0	30,000	21,300,000	23,400,000
7	5 ,,	9,700	2 18 0	29,000	20,590,000	22,620,000
8	5 ,,	10,300	2 16 0	28,000	19,880,000	21,840,000
9	5 ,,	11,400	2 15 0	27,500	19,525,000	21,450,000
10	5 ,,	12,700	2 14 0	27,000	19,170,000	21,060,000
11	5 ,,	14,200	2 13 0	26,500	18,815,000	20,670,000
12	5 ,,	16,000	2 12 0	26,000	18,460,000	20,280,000
13	12 ,,	17,500	2 10 0	25,000	17,750,000	19,500,000
	97 years	—	—	2,889,457	2,051,514,470	2,253,776,460

SUMMARY—*continued.*

Period	Term	Initiatory Sinking Fund per million	Amount of each Annuity	Annual charge on £1,000,000	Annual charge on £710,000,000	Annual charge on £780,000,000
			Plan No. 2.			
		£	£ s. d.	£ about	£ about	£ about
1	30 years	4,500	3 9 0	34,500	24,495,000	26,910,000
2	30 ,,	6,400	3 0 0	30,000	21,300,000	23,400,000
3	30 ,,	10,600	2 10 0	25,000	17,750,000	19,500,000
	90 years	—	—	2,663,164	1,890,846,440	2,077,267,920
			Plan No. 3.			
1	40 years	5,000	3 10 0	35,000	24,850,000	27,300,000
2	47 ,,	6,300	2 10 0	25,000	17,750,000	19,500,000
	87 years	—	—	2,564,185	1,820,571,135	2,000,064,300
			Plan No. 5.			
1	30 years	5,000	3 10 0	35,000	24,850,000	27,300,000
2	30 ,,	7,100	3 0 0	30,000	21,300,000	23,400,000
3	24 ,,	12,300	2 10 0	25,000	17,750,000	19,500,000
	84 years	—	—	2,547,752	1,808,903,920	1,986,846,560
			Plan No. 6.			
1	10 years	5,000	3 10 0	35,000	24,850,000	27,300,000
2	10 ,,	5,700	3 8 0	34,000	24,140,000	26,520,000
3	10 ,,	6,700	3 6 0	33,000	23,430,000	25,740,000
4	10 ,,	8,000	3 4 0	32,000	22,720,000	24,960,000
5	10 ,,	8,700	3 0 0	30,000	21,300,000	23,400,000
6	10 ,,	10,700	2 18 0	29,000	20,590,000	22,620,000
7	10 ,,	12,400	2 14 0	27,000	19,170,000	21,060,000
8	10 ,,	14,700	2 10 0	25,000	17,750,000	19,500,000
9	9 ,,	17,200	2 5 0	22,500	15,975,000	17,550,000
	89 years	—	—	2,652,127	1,883,010,170	2,068,659,060
			Plan No. 7. For the first eight periods as Plan No. 6.			
9	10 years	14,700	2 0 0	20,000	14,200,000	15,600,000
10	1 year	6,200	0 13 0	6,400	4,530,000	4,980,000
	91 years	—	—	2,655,982	1,885,747,220	2,071,665,960

Comparison of Cost of Different Systems.

Plan No. 6.

Diminishing Sinking Fund or Annuities		£2,652,127
Perpetual Annuities £30,000 × 89 years =	£2,670,000	
Add debt still owing	1,000,000	3,670,000
Annuities for terms of years, £3 4*s.* 8*d.* each × 89 years = £287 15*s.* 4*d.* × 10,000 . . .		2,877,666$\frac{2}{3}$

Plan No. 7.

Diminishing Sinking Fund or Annuities		2,655,982
Perpetual Annuities £30,000 × 91 years =	£2,730,000	
Add debt still owing	1,000,000	3,730,000
Annuities for terms of years, £3 4*s.* 4*d.* each × 91 years = £292 14*s.* 4*d.* × 10,000 . . .		2,927,166⅔

I now request your attention to plans 6 and 7, which are drawn up especially for practical purposes, not to demonstrate the capacity for modification of my principle, or the vastness of the economies to be effected. Examining plan No. 6, it is noticeable that after 40 years the excess for sinking fund entirely ceases. From the 41st to 50th year the annual payment is the same as for perpetual interest, and from the 51st to the last year it is decreasingly less. The total disbursement on account of the sinking fund is, in the forty years, some 140,000*l.* per million, or 99,400,000*l.* for the funded debt; while in the last 39 years the total saving is 165,000*l.* and 117,150,000*l.* respectively, which more than compensates for the early sacrifice. If we study the problem from an every-day, instead of a theoretical, standpoint, it is evident that to redeem the debt need cost the country NOTHING. This generation lays out 99,400,000*l.* by 40 instalments, to be returned with interest to its successors. If 89 years is considered too long a term, the payments from the 41st year can be equalised at 3 per cent. on the capital, and the debt annihilated in 81½ years. The net cost of redemption will then be 99,400,000*l.* or 14 per cent.

I will now ask you to inspect plan 7. You will observe that the same method of repayment is continued up to the 80th year, but that from the 81st the annuity is 2*l.* instead of 2*l.* 5*s.*, and the annual payment is fixed at 20,000*l.* instead of 22,500*l.* per million. In introducing this variation my object is to impress upon the mind, with redoubled force, the extraordinary potency of compound interest, when judiciously applied. Although the funded debt charge for the final period averages 1,775,000*l.* less by the last plan, liquidation occupies little more than a year longer; while the aggregate sum required for interest and sinking fund is augmented by 2,737,050*l.* only. Prolonging the term of redemption has the effect of showing up the new philosophy in more brilliant colours—the saving when compared with perpetual annuities being 63,145*l.* per million more, or when compared with annuities for terms of years or cumulative sinking funds, 271,184*l.* 13*s.* 4*d.* against 225,539*l.* 13*s.* 4*d.* The correct figures for the funded debt are, as against perpetual annuities, 12,689,830*l.* by plan No. 6, and 52,552,780*l.* by plan No. 7. This is excluding the 710,000,000*l.* capital paid off. When compared with annuities or cumulative sinking fund loans terminating in 89 or 91 years, the net savings are over 160 and 192 millions respectively. The limitation of time prevents notice being taken of many other important phenomena which occur to my mind, but I trust sufficient information has been given to enable economists and financiers to thoroughly investigate this neo-philosophy in sinking funds and annuities, and that sooner or later we may see its principles adopted in this and other countries.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *What is Capital? The Contradictory Responses of Economists to this question examined from the ground of Actual Fact and Life.* By W. WESTGARTH.

The author, after alluding to the late Mr. Bagehot's remark, that many who were conversant with economic theory were not so with economic facts, and *vice versâ*, went on to illustrate this by the case of capital, which is still so disputed a

subject in Political Economy. The question What is Capital? is still answered by economists in a most various and unsatisfactory way. Approaching the question from the side of a large conversancy with economic facts, he would point out where the conclusions of economic theory appeared to him at variance with the facts of life. He first gave the prevailing theories as to capital, and then contrasted them with what capital actually was in the world of fact and life. Adam Smith's view was, that everything dealt with to yield revenue or profit was Capital. This view, although still partially held, had been largely departed from since, and the prevailing view now was, that capital was that only which was concerned in production. Then again arose the question of two kinds of capital, the fixed and the circulating, and what rule or principle distinguished them. Here Smith's criterion was fixity as distinguished from mobility; but Ricardo had suggested rather relative durability, and in this had carried most economists with him, so that the prevailing view now was that things of a durable kind, as land, buildings, railways, were of fixed capital, while perishable or renewable things, as food, clothing, furniture, were of circulating capital. But as Professor Jevons and others admit, there is no clear line between a throng of things which are neither very durable nor yet very perishable. He then passed to a suggestion of Mr. Jevons, which he noticed favourably as tending to a correct view of capital. This is in effect that the so-called fixed capital is not itself capital, but is that which has had capital spent upon or sunk in it. He proposes thus to distinguish a 'free' from an invested capital. But as to this free capital, he falls back upon the 'production' idea, already adverted to, and limits capital to articles of food, clothing, furniture, and such direct needs of 'labour of all kinds and classes.' Lastly, as to the origin, maintenance, and increase of capital, most economists are agreed that these all result from saving, abstinence, and improving industry, so that the less the spending of what is produced, the more the capital, and on apparently to indefinite increase.

All these views Mr. Westgarth considered to differ more or less from that of the capital of fact as confronting us in actual life. This capital we see to be one fund—one homogeneous fund we might call it—which supports indiscriminately not production only, but all exchange or business life. He insisted, as speaking from the world of fact, that exchange was essential to the idea of capital. What caused exchange was the subdivision, or, to speak more comprehensively, the association of labour. With the association of labour, he remarked, we enter upon Economic Science, and it has thus, in this its limitation, a sufficiently marked distinction from the far wider Sociology, or the Science of Society. Capital, then, is the fruit of exchange. It consists of the stock of things which arise and are maintained as the needs of exchange. These stocks are mainly of three kinds: first, raw materials, or things in preparation for our use; second, the things prepared, and for sale in the shops and markets; and third, the prepared things which are not passed out of exchange for 'consumption,' but kept as the 'rolling stock' of trading or exchanging life. The chief and most notable item of this third kind is money. Money is simply one kind of goods used to value the other kinds, and where independently originated, it has always made its first appearance in this simple way. Coinage and the change of material for the 'precious metals' were afterthoughts to increase convenience, but they noways altered relationships. The fund of capital then consisted of goods and money—of these indiscriminately, as one and the same class of things. This fund was distinguished from the so-called fixed capital, which, as to its leading idea, was not capital at all, but only agency, which agency, in conjuction with that of man himself, enabled us to produce the real things of capital, namely the requisites of our direct use. Land, for instance, is such agency, and only its crop belongs to capital. These direct requisites are capital while within the sphere of exchange; outside of exchange they cease to be capital. Thus the limitation or law of capital is that it constitutes the stocks required for the time being by exchange. As exchange extends in a country and larger stocks are needed, there is more capital to the country. What causes exchange or trading to extend, in spite of this cost of larger capital, is the increased economy of production gained by the larger scale of business. All trade extension

is an everlasting battle between, on the one hand, the increased profit by cheaper production, and on the other, the increased cost of the larger capital requirement. Successful trade extension is that which, in increasing a country's income, increases concurrently also the total of its capital. There is then a 'Law of Capital,' and these are its chief elements.

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2. *Remarks and Statistics relating to Swansea Usages and Customs as they affect the Sellers of Foreign or Colonial Copper Ores. By* Wm. Henderson.

I have chosen the occasion of the meeting of the British Association at Swansea as a fitting time and place for the discussion of this very important subject. It is a matter of great local importance, and here it is most likely to receive an intelligent and practical treatment. No doubt from the standpoint of the sellers of foreign ores, the clamant evils of the system have long ago called for redress. For many years we have suffered from delays, inaccuracies, and all the evils inherent in this antiquated system, and striven to remedy it as best we could, and have succeeded, where we had to deal with rich ore, reguluses, or precipitate, to a certain extent, and completely, so far as Chili bars are concerned; but to the very large quantity of poor ores, such as the Spanish and Portuguese ores, the whole of the Swansea system applies in all its inconsistency and rigour; and my object in this paper is to show the hardships we are altogether unnecessarily subjected to, and to propose a remedy. I may also here premise that we do not complain of the actual price paid us for our ores, as I do not believe that we should get a penny more were the system changed to-morrow. But what we complain of is the system by which that price is arrived at, and the enormous waste of time before we get 'agreed' results. I purpose treating this subject under the following heads:—

1. Swansea public sales or 'ticketings.'
2. Sales by private bargain at Swansea and elsewhere based on Swansea sales.
3. Sales by private bargain based otherwise than Swansea.
4. Weights and allowances.
5. Dry assay and its relations to the truth, as shown by actual results by smelting and wet process. Time consumed in getting settled results—differences.
6. Wet assay.
7. What ought to be the simple basis of price?

1. *Swansea Public Sales or Ticketings.*

Public sales of copper ores at Swansea, several years ago, used to be very regularly held once a fortnight, and the quantities of ore were then very large and important. This is now no longer the case. For the year 1877 there were only twenty-three sales; for 1878, only eighteen sales; and for 1879, only fifteen sales. The quantities sold were insignificant—being for the three years collectively 112,504 tons.

The usual custom with foreign ores which are to be disposed of by public sales is as follows:—They are usually consigned to one or other of the ore yards, such as those of Messrs. Bath & Sons, or Messrs. Richardson & Sons, where the ore is landed, and, if necessary, crushed and put out in square or oblong piles about 2 to 2½ feet deep, and in parcels of from 50 to 100 tons and less. These are generally put forward for next sale, and a day is appointed for sampling, when intended purchasers are represented as well as the seller. A period of fourteen days is allowed between the date of sampling and the day of sale, which is considered necessary to allow the assays to be made. On an average it takes fourteen days more to prepare and crush the ore previous to sampling, and all this is attended with a very serious expense, besides the delay. As we do not know when another sale will take place at Swansea, we save time and lose nothing by adhering to previous sale.

Two tables were here given, showing what time is lost between the delivery of the ore and the settlement of the assay and price.

During the whole of these numbers of days, ranging from sixteen, which appears to be the shortest, up to sixty-two days, we cannot deliver our invoices, and have to wait for our money all that time. This great hardship is further aggravated to the importer who sells his raw ore to the sulphuric acid makers for sulphur value only, and takes back the cinders. These have to be again sampled and assayed, with the delays repeated. If he is also a copper extractor, as I am, and sells his precipitate, that has again to be sampled and assayed, and the same delays repeated, so that it may be quite a common event that from the time of landing till the time of realisation eight months may elapse, and the same copper be assayed three times. The costs by sale at public ticketings are very considerable, amounting in Spanish ores to fully half the freight, which, with present low prices of copper, may be all the profit. This is not the custom when sold by private bargain, as these sales as a rule are generally *ex* ship. It is, therefore, evident that if an importer can sell his ores to arrive *ex* ship by private bargain, he will not send them to the Swansea sales; and surely this is not a state of things conducive to the prosperity of Swansea or its industries.

2, 3. *Sales by private bargain at Swansea and elsewhere based on Swansea sales.*

The great bulk and value of these sales are made *elsewhere* than at Swansea and the *preceding* sale; or, if any Swansea sale takes place on the day of sampling, that sale is taken as the basis of price. The object is, of course, to save time, and one has to take the risk of a rise or fall in the price of copper between the dates of sale and that of delivery. Our friends the copper-smelters at Swansea will, however, admit that so far as the produce of Spain and the economical treatment of the raw Spanish or Portuguese ores are concerned, or even for the smelting of the burnt ores, the processes of Swansea were quite unable to deal with the large quantities in any economical way. With the raw ores, as a rule, the very large percentage of sulphur, viz. 48 per cent., would have been worse than wasted, as it would have cost something considerable to *calcine* such ores, rich in sulphur and poor in copper, down to the point to make them produce *per se* (or even mixed with other calcined ores) a sufficiently rich regulus. Besides the enormous increase of nuisance, and even when in later days the sulphuric acid manufacturers came to use the sulphur, the cinders still contained 60 per cent. of metallic iron, and which when sent to Swansea, from such distant places as Newcastle and Glasgow, at heavy freights, only 4 per cent. to 6 per cent. of the weight was paid for, and the whole of the iron contents were lost. By the introduction of my wet process at this juncture, the shipment of these burnt ores from all the districts of large consumption was rapidly stopped, and the ores treated on the spot, saving the freights and iron ore, and yielding much more perfect results for copper—thus preventing very large quantities of ores coming to Swansea. And so in like manner the enormous yields of the Spanish and Portuguese mines (which are constantly increasing), over and above their possible sales for sulphuric acid purposes at home and on the Continent has gradually led to great extension of the slow process of cementation from the poorer grades of ore, produced at very small cost, in enormous quantities, reckoned by hundreds of thousands of tons, for each of the uncovered mines per annum a very large and increasing annual production of copper, as precipitate, of from 50 to 75 per cent. produce is annually obtained.

Another reason why the public sales at Swansea have decreased, and are therefore no longer a fair basis for private sales made elsewhere, is the most serious of all. By the opening up of short railways to the mines, and the great development of coal mining, Chili now sends most of her produce to this country, as Chili bars, or in blocks containing about 96 per cent. pure copper. So serious is this production, that it may be stated roughly as a fact that Chili exports as much copper in ores, reguluses, bars, and ingots as all the rest of the world produces, and almost the whole of this is sold by private bargain, and the price is regularly quoted every business day, and virtually rules the price of copper.

The statistics given below from the Board of Trade returns for the last three years amply prove what a small proportion of the copper imported is sold at Swansea public sales, and how much by private bargain.

Board of Trade Returns of Imports for Years 1877, 1878, 1879.

Specification and Country	Quantities			Values		
	1877	1878	1879	1877	1878	1879
	Tons	Tons	Tons	£	£	£
Copper Ore from Chili . .	7,949	2,349	461	115,933	30,694	8,355
Do. Cape of Good Hope . .	14,060	12,789	13,629	258,839	241,373	232,956
Do. British North America .	38,612	34,630	25,054	256,215	191,505	127,581
Do. other countries . .	54,845	53,177	48,685	533,723	456,561	395,605
Total . . .	115,466	102,945	87,829	1,164,710	915,133	764,497
Regulus (incl. Precipitate) from Chili	17,031	11,455	15,666	531,237	342,363	415,996
Do. other countries . .	16,670	21,955	30,264	667,312	798,574	1,073,160
Total . . .	33,701	33,410	45,930	1,198,549	1,140,937	1,489,156
Unwrought or part wrought from Chili	25,958	22,785	33,534	1,810,859	1,434,403	1,957,049
Do. from Australia . . .	11,010	8,661	9,845	851,759	610,640	638,632
Do. other countries .	3,248	7,914	3,291	225,753	513,232	207,494
Totals . . .	40,216	39,360	46,670	2,888,371	2,558,275	2,803,175
Pyrites	680,033	577,719	481,622	1,646,132	1,332,934	1,051,015
Grand Totals . .	869,422	753,434	662,051	6,897,762	5,947,279	6,107,933
Public Sales at Swansea . .	45,674	35,581	31,249	407,969	164,914	134,069
Sales elsewhere by private bargain	823,748	717,853	630,802	6,489,793	5,782,365	5,973,864

4. *Weights and Allowances.*—It used to be the custom at Swansea and elsewhere to weigh the ores, reguluses, and precipitate in hand barrows of 3 cwt. each, by beam and scale, thus giving seven weighings to the ton of 21 cwt. For some years, however, this custom has been departed from, and 2 cwt. barrows substituted, thus requiring 10½ turns of the scale for every ton of 21 cwt. But over and above this allowance a draftage of 24½ lbs. per ton of 21 cwt. is demanded from sellers of foreign or colonial ores. Why this anomaly exists it is impossible to guess, when no such allowance is asked for in Cornish ores. What even is the use of maintaining the 21 cwt. to the ton except to complicate and obscure accounts? Refined copper is not sold at 21 cwt. to the ton; and no such absurd allowances as 24½ lbs. per ton, nor is it weighed in 2 or 3 cwt. lots. Ingots, cakes, and tiles are all weighed carefully in 10 cwt. lots with just the turn of the scale, and the seller makes an allowance at the time of about two pounds to the ton, as it is found by experience that a certain amount of scale comes off in handling and transit, and this allowance is to insure delivery of nett weight to the purchaser on delivery, and experience shows that this allowance is ample. In selling or buying Chili bars, which are partially refined copper of about 96 per cent., an allowance of 4 lbs. on the ton of 20 cwt. is all that is allowed, and I think this is perfectly fair, for the refiner has to sustain the risk of scaling and abrasion both to and from his refinery.

There can be no argument in favour of the maintenance of the 21-cwt. ton and allowance, except some antiquated custom, and there is much in favour of its immediate abolition. We, the sellers of foreign ores, do not for a moment suppose that so far as price is concerned the abolition of these absurd and antiquated customs will secure us any advantage whatever. We are perfectly aware that the receiving of these allowances by the buyer, and the giving of them by the seller, have all been taken into calculation by both. Our only argument here is, what is the use of introducing gratuitously into a simple calculation complications of this sort, which are admittedly discounted previously? We consider this a grievance that only requires to be stated to be admitted, and as its maintenance benefits no one, but wastes time and leads to needless book-keeping, we earnestly trust our friends the smelters will agree to their early discontinuance.

5, 6. *The Dry Assay and its relations to the truth, as shown by actual results, as obtained by Smelting and by the Wet Process with works where the Precipitate is refined, and Copper sold as B. S. or Tough Cake. The Wet Assay tested in the same manner, and as compared with the Dry Assay.*

It will be more convenient to treat these two divisions of my subject together. I do not intend here to enter into any description of either the dry or the wet assay, and their modes of operation. In the Chemical Sections of this, or a future meeting, I hope to have an opportunity of discussing these fully.

What we importers of foreign ores have chiefly to complain of in the method of the dry assay is the unreasonably long time it takes to get agreed results, and the constant disputes, which require a considerable amount of very unpleasant and vexatious correspondence, which generally ends in a reference; and all this consumes valuable time. I have enough and to spare of statistics to prove this argument against the dry assay method—the long and inconsistent delay in settling results—a delay and uncertainty in which the disputes are so chronic that I venture to say no other class of merchants would have endured them one year without seeking some remedy.

A set of results furnished me by Messrs. Mason & Barry show that no possible reliance can be placed upon the dry assay, as in the same cargo, delivered from the same ship, but divided amongst several customers, totally different results are obtained. Now, I am not prepared to go so far as this, as it goes quite against my general experience. In my view, it is a perfect proof that the mode of sampling is utterly wrong, when the sampler for the buyer and the sampler for the seller are permitted to take their samples by running over a series of loaded trucks and each chip off about a shovelful from a six or ten ton truck from large pieces of ore. Mix them together and call this a sample!! The results of divided cargoes—which, if properly sampled, would go to prove the dry assay utterly worthless, are, when not certain on the point of sampling, misleading—are yet so instructive, that I have ventured to give them here as facts which bear somewhat of an important argument against the dry assay.

Then against the dry assay we have a special charge that the assayers very often disagree, and the result is a reference to a third assayer with a corresponding loss of time. This has very frequently to be undergone, especially with burnt ores, and in most cases the third assayer agrees with neither of the others.

As a contrast to this, I recently caused the Seville Sulphur and Copper Company to send a sample from their usual imports from their two mines, one comparatively rich and the other very poor, to five of the best known chemists who make a speciality of analysis of minerals, and I give below their results, and it will be seen how closely they agree.

	ex Betty Russell. I.	II.	III.	*ex Bella Rosa.*
Edward Riley, London . . .	6·752	6·808		3·42
Fred Claudet, London . . .	6·830	6·825	6·835	3·48
James S. Merry, Swansea . . .	6·75	6·85	6·90	3·47
Alfred H. Allen, Sheffield . . .	6·82			3·30
John Clark, Ph. D., Glasgow . .	6·81			3·42
Average		6·80%.		3·42%

It will also be seen that the dry assay is uniformly too low, and always considerably short of the truth. This is proved not only by its difference from the wet assay, but also by actual results obtained by smelting, where the *surplus copper* forms a very considerable portion of the profit. But the wet assay is proved to be the true assay by results obtained on the large scale when my process of extraction is used, and the precipitate produced refined. I give the results from four different works, in situations far distant from each other, and all for the same year. The works are placed in the order of their erection, D being the most recent and the most perfect in construction.

Specification	A	B	C	D	Total and Averages
Ore Calcined . . .	7,940·65	9,833·063	23,074·76	14,485·975	55,964·448
Copper—Dry Assay . .	311·89	252·333	690·053	466·465	1,720·741
Do., Wet Assay . .	416·356	382·110	984·830	650·210	2,433·506
Copper produced . .	387·069	338·855	919·284	636·768	2,281·976
Gain on Dry Assay . .	75·179	86·522	229·231	170·303	561·235
Loss on Wet Assay . .	29·287	43·255	65·546	13·442	151·530
Percentage—Dry Assay .	3·93	2·57	2·91	3·22	3·07
Do., Wet Assay . .	5·24	3·89	4·15	4·49	4·35
Produced	4·87	3·45	3·88	4·39	4·08
Difference between Wet and Dry Assay . .	1·31	1·32	1·24	1·27	1·28
Gain on Dry Assay . .	·94	·88	·97	1·17	1·01
Loss on Wet Assay . .	·37	·44	·27	·10	·27
Surplus	23·9	34·2	33·3	36·3	32·90

These results were obtained ten years ago; but with increased experience and better plant the produce by the wet assay has been obtained with great regularity to within the second place of decimals. The results shown in the above table prove conclusively that the dry assay is not within 33 per cent. of the truth; for these four works in one year, by the treatment of nearly 56,000 tons of ore, actually refined and sold no less than 561 *tons of copper more than the dry assay declared existed in the ore.* There can be no mistake about a reality of this kind; and what are we to say in favour of a system which is so misleading? In any other branch of business such proved inaccuracies would never be tolerated a moment; and the worst of it is, that the lower the percentage of copper in the ore the greater the proportional difference. By reference to tables supplied by Messrs. Mason & Barry, we see that when the dry assay says the ore contains 1 per cent. copper, the wet assay says at least 2 per cent.; so that if these four works had been working ores of what the dry assay called 1 per cent., they would most assuredly have got 2 per cent. out, or 100 per cent. surplus. A very amusing instance of the utter uselessness of the dry assay for poor ores was shown in the case of the Alderley Edge ores, which were a very pure sandstone mixed with a good deal of sulphate of barytes, and just stained green with carbonate of copper. The wet assay gave readily 1 to $1\frac{3}{4}$ per cent., but the average of the ore treated was 0·92 per cent. I knew, of course, that the ore would be extremely difficult to assay by the dry way—in fact, I could get nothing. We sent two samples to two Cornish assayers, and they could find nothing either. Now, here was an extraordinary thing. A copper mine raising 1200 tons a month, paying a lordship of nearly £3000 a year, and dividing handsome dividends for eighteen years, all out of nothing. We cannot push the argument against the dry assay further; it stands self-convicted.

7. *What ought to be the simple basis of price?*

I am quite aware I approach the most difficult part of my subject, but I believe there is a clear way out of the difficulty. I have, I think, proved that—so far at least as poor ores are concerned—the dry assay is utterly worthless. Of course I assume that no one of any intelligence will be found to maintain that

21-cwt. tons and 24½ lbs. draft per ton can possibly be retained with any show of reason. As to the dry assay on rich ores and reguluses, I think I have clearly proved that, at all events as far as precipitate is concerned, it is always below the truth by a good many per cents., and the same must be said of all ores between 10 and 90 per cent. On the other hand, Chili bars, which have only to be refined, should be refined by the process they have to go through to make them fine copper, and I think the dry assay is the nearest corresponding process they could be subjected to. At all events, the wet and the dry assays almost entirely agree in Chili bars; an occasional difference of ½ per cent. is entirely due to the opinion of the refiner whether he has actually got refined copper or not—'B.S.' or 'T.C.' But with precipitate it is very different, particularly that produced by the 'salt process;' there is always a difference of at least 4 per cent. In the early days there used regularly to be 11 per cent. difference, but now, though not satisfactory, it is much better. Still, I think all ores and reguluses, including precipitate, ought to be assayed by the wet method, and the results stated in whole numbers and decimal fractions, and be paid for including the second place of decimals. The basis of price should be in proportion to the official price of refined copper as quoted on the day of sampling, or if there is no official or quoted market price on that day, then the last preceding quotation. As there are several qualities of refined copper, the medium quality, or what is known as 'Tough Cake,' would, I think, be fairest. Chili bars, which form such a large proportion of the material out of which refined copper is produced, and are officially quoted every market day, might also be taken; but as these may cease to be produced, it would be better, I think, to base the price on the price of 'Tough Cake.' Then, as to the proportional price for all percentages of ores, leaving a fair margin to smelters and extractors, this can be arrived at very much as is done at present. A complete set of tables, I would suggest, could be constructed by a committee of smelters, extractors, and importers, and these should be printed by authority of this committee, and available to any purchaser. I would suggest also that a committee of chemists should also settle and publish with the book a very minute description of the best known wet method of assay, and that this method of assay be, and remain until altered by authority, the *standard method of assay*. It would not be necessary in these tables, in my opinion, to go further than to state opposite each percentage or bracketed set of produces how many shillings and pence per *unit* these produces are worth. Anyone with the most rudimentary knowledge of figures from these data would find the price per ton of ore. By means of the wet assay, which can be made with great rapidity and exactness, and with this authoritative data as to the value per unit, invoices could be rendered within a few days, or even hours, after sampling, with perfect confidence.

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3. *Progress of the English Stations in the Hill Regions of India.* *By* HYDE CLARKE, *V.P.S.S.*

Mr. Clarke stated that the Himalayan ranges to the north possess the cool climate of England, and that Englishmen thrive there. This had early attracted the attention of our great administrators, who, beginning with Simla in 1818 and Darjeeling in 1828, had formed a series of stations, which had performed the functions of sanitaria, watering-places, and military posts, of metropolis and capitals, and latterly also of centres of tea-culture. A chain of hills passed as a backbone through India on the west, in which were seated some minor stations. He had shown how by telegraph connection these towns were as well suited as the unhealthy cities of the plains for governmental and military purposes. In a series of statistics he illustrated the condition of the tea and cinchona plantations and the breweries. He estimated the hill products as approaching a million in value, including 10,000,000 lbs. of tea and 3,500,000 lbs. of coffee. The gross imports from the foreign hill states he estimated at about 2,000,000*l.* yearly. All this trade was capable of extension by careful administration. Thibet and China are closed to us; where Russian power extends our trade ceases. Nepaul excludes us, and our own feudatory in Kashmere but grudgingly allows us access. The oppression and misgovernment of

the latter country require a removal of the ruler. In a political point of view it was admitted that the hills, although so little used, afforded suitable quarters for a large portion of our English army, which would greatly increase its efficiency. The development of the hill regions would create an available reserve, while India would obtain what was essential for its welfare, greater security from aggression from without and from dissension among the various conflicting races within the peninsula. It was, however, chiefly in reference to the interests of civilisation in the advancement of India that the development of the English population in the hill countries of India was to be regarded. He showed too that the aboriginal races might in this respect receive great benefit. The progress which had been made in the hills within the last twenty years, almost without care, showed what was to be effected in the future.

Section G.—MECHANICAL SCIENCE.

President of the Section—James Abernethy, V.P. Inst. C.E., F.R.S.E.

THURSDAY, AUGUST 26.

The Section did not meet.

FRIDAY, AUGUST 27.

The President delivered the following Address:—

As time will not permit of a generally detailed description, I propose, in the Address which I have the honour and pleasure to make as President of your Section, to describe generally the past and present condition of the port of Swansea, as typical of the rise and progress of the various ports in the Bristol Channel within the last half-century, and the vast improvements which have been effected in the nature and extent of the accommodation provided to meet the requirements of the shipping of the present day as regards dock facilities and appliances for the rapid and economical loading and discharging of their cargoes rendered necessary by the amount of active competition in every branch of commerce, both export and import.

I propose to confine myself in this address generally to the engineering history of Swansea Harbour, but I think it necessary, in the first place, briefly to describe certain features of the Bristol Channel, resulting in the peculiar advantages its harbours possess over those of the eastern coast, due to the greater tidal range.

At its entrance between St. Govan's Head on the north and Hartland Point on the south, its width is 42 miles, gradually contracting, until at King Road at the mouth of the River Avon, 92 miles distant, its width is only 4½ miles, the result being a proportionate elevation of the tidal wave in its progress upward, so that in Swansea Bay spring tides rise 28 feet, at Cardiff 35 feet, and at Avonmouth 40 feet, and in consequence engineers have been enabled to provide for the entrance of the largest class of shipping by providing at the various docks recently constructed a greater depth of water than is generally practicable on the eastern coast. The cill of the dock at present in process of construction at Swansea will have a depth over it at spring tides of 32 feet, while the existing cill of the Roath Dock at Cardiff has 35 feet 8½ inches over it; that of the Alexandra Dock at Newport 35 feet, and the Avonmouth Dock 39 feet—greater depths than exist over the lock cills of any of the ports on the eastern coast generally.

It would extend my address to an unnecessary length to describe the vast improvements which have taken place at all the ports in the Bristol Channel within the past half-century. The port of Swansea may fairly be taken as a type, inasmuch as from its position it has natural difficulties to contend with, requiring, as at Cardiff, extensive works seaward in order to provide the requisite depth of water, such works not being necessary in the case of the docks at Newport, Avonmouth, or Portishead.

As regards its situation, the port is placed nearly in the centre of Swansea Bay,

at the mouth of the river Tawe, partially sheltered from prevailing winds by the Mumbles Headland bearing from the harbour entrance south-west three-quarters west, the shelter from that headland affording good anchorage as regards holding ground, but subject to the range of the sea in south-westerly gales. The entrance to the port is exposed from south-west three-quarters west to south-east, the heaviest seas occurring when the wind is south-westerly or directly up the Channel.

Previous to the year 1794 no engineers appear to have been consulted as to the improvement of the port, which at that period simply consisted of the bed of the River Tawe, the latter discharging over the flat foreshore after passing through a small subsidiary bay, termed Fabian's Bay, lying between two points of land called Black Point and Salthouse Point, the entrance being fully exposed to the range of the sea from the points of the compass before enumerated, and consequently blocked up by sand driven into it by the action of south-westerly seas, and only accessible at spring tides in fair weather by a small class of coasting vessels.

In the year 1794 the then Trustees consulted Captain John Huddard, F.R.S., who at that time had the reputation of being an eminent marine engineer, and a perusal of whose report shows that, having regard to the meagre knowledge of harbour improvements at that period, he possessed great powers of observation and considerable practical engineering knowledge. In his first report, which is of considerable length, dated 24th September 1794, he states that he was called upon by the Trustees to answer various queries generally bearing on the possibility of providing an increased depth of water by improving what is termed the 'bar' or sand carried into the navigable channel by the tidal action in south-westerly gales, and the protection of the harbour entrance from the inrun of the sea during those winds. The condition of the harbour at that period in regard to depth can be inferred from the following passage in his report—'On the 5th August I found only 8 feet of water in the harbour, and in the evening of the 31st July a vessel of about 13 feet draught of water, in sailing out of the harbour, grounded upon the bar, where she remained till the 10th August, when the tide rose to take her off; and every ship in the harbour loaded to that draught of water, and ready to sail at that time, must suffer the same detention.'

Captain Huddard gave as his opinion that a greater depth of water could not be obtained, nor the drifting of the sand from the effect of the sea into the entrance channel prevented, without the construction of piers, which he termed the eastern and western piers, the first extending from Black Point and the latter from Salthouse Point, which piers in consequence of his recommendation were subsequently constructed. Captain Huddard further observes that the increased depth anticipated consequent on their construction 'would continue so long as the tide is suffered to flow up the river as at present,' but at the same time it would appear that a project was then entertained, often since revived, for damming the river and converting it into a floating dock, as his report contains the following passage—'Should the river be embanked for a floating dock, sluices will be necessary to clear away the silt out of the channel which the sea will deposit in the outer harbour; for though the harbour of Swansea will not be so liable to silt as many others from the strength of the tide in the Severn being thrown off by the Mumbles and Nash Points; yet, in fresh gales, the same being impregnated with mud, will deposit it in the harbour and require a current to clear it out of the channel.'

The construction of the West Pier, as recommended by Captain Huddard, was carried out, and in May 1804 he was again called on to report. He states that the only alteration which he observed on his second visit was that the sand to the extent of 270 yards south of the pier head was worn down nearly one foot, but that what was termed the 'Bar' seaward was higher than the harbour entrance, and that it was absolutely necessary to complete the Eastern Pier in order to secure a permanent depth of water and to afford the necessary protection from south-westerly winds. The Eastern Pier was in consequence constructed, the result being the prolongation of the river current and the driving of the bar further seaward, and in the year 1831 it was reported that a depth of 21 feet existed over it at spring tides, as anticipated in Captain Huddard's report of 1794.

In the year 1826 the Trustees consulted Mr. Telford, and he reported on February 5 of the following year. At that period what was termed the harbour was simply the bed of the river Tawe; the shipping lying within it were endangered by exposure to the action of heavy floods, and he recommended that the present new cut should be made as a channel for the river—no doubt an important and necessary work; but he again revived the old engineering heresy of recommending the conversion of this new cut and of the old harbour into floats with a river overflow and draw sluices. He further recommended the direction of the ebbing current seaward by slag banks, in order to act upon the bar. These propositions of Mr. Telford were generally approved of by Mr. H. R. Palmer in a report addressed to the Trustees in January 1831, and he further recommended the prolongation of the Western Pier.

Similar propositions were recommended by other engineers, among them the late Mr. Jesse Hartley; but fortunately for the future of the port of Swansea, none of the works for the conversion of the river into a float were executed. The new cut, or channel, for the river was commenced in 1840, and finished in 1844, the effect being to materially lessen the risk to shipping lying within the harbour or original bed of the river during floods, and in giving a better direction to the ebbing current.

In 1845, what is termed the Pottery Entrance was constructed under the direction of Mr. Rendel, with a double cill, as a provision for the canalising of the river or the new cut at a future period. The masonry of this entrance I found completed at the period of my first visit to Swansea in the month of February 1849, and the project was still entertained of converting the river and new cut into a float, relative to which I reported in the following words:—'Any interference with the channel of the river or new cut which would prevent the free influx and reflux of the tide, would, I am of opinion, be most prejudicial to the harbour entrance. In times of flood, the river current is no doubt an active agent in deepening and removing obstruction from the entrance channel; but, under ordinary circumstances, its volume is too small to have any material effect. On reference to sections taken by the late Mr. Price, I find that 40,000,000 cubic feet or thereabouts of tidal water ebbs each tide from the river channel alone, independent of the backwater from Fabian's Bay, and I am of opinion that, although the land-floods are active agents in deepening and removing obstructions from the entrance channel, the tidal water is the main agent in maintaining and keeping it clear, and that every facility should be given by deepening the bed of the river to aid its upward flow, and that in proportion as the bed of the river is lowered the entrance channel will be deepened.' To that opinion, expressed upwards of thirty years ago, I still adhere. The system of discharging a volume of water at the period of low tide from reservoirs, and thereby creating a shallow stream as a means of preserving a navigable channel and a sandy foreshore, is, in my opinion, entirely futile, and in the case of several important Continental harbours threatens seriously to interrupt the regular postal service between this country and the Continent.

Upon my visit in 1849, with the exception of the masonry of what is termed the Pottery Entrance and the various wharves on each side of the old river-bed and of the New Cut, no works had been executed of any magnitude; the harbour still consisted of the original river-bed composed of hard gravel worn into irregularities by the occasional action of floods, and the superior class of shipping engaged in the copper ore trade was constantly strained in taking the uneven ground. As regards communication with the harbour, no railways were in existence, and I used to make the journey from Aberdeen, in Scotland, to Swansea, entirely by coach. The gross revenue of the harbour was about 7000*l.* per annum at that time; during the present year it is estimated at about 60,000*l.*

After considerable discussion, the Trustees determined in November 1849 to convert the tidal harbour, or old bed of the river, into a floating dock with an outer half-tide basin, of the respective areas of 11 and $2\frac{3}{4}$ acres, the half-tide basin entrance being 60 feet in width, with a depth over the cill of 25 feet 6 inches, at high water spring tides. Between the half-tide basin and dock, a lock was constructed, 160 feet in length and 60 feet wide, with a depth over the cill of 22 feet 6 inches; these

dimensions were considered, at the time, ample for the largest class of shipping frequenting the port. At that period the number of steam in comparison with sailing vessels was insignificant, and the Transatlantic service between this country and America was only in contemplation.

Some difficulty was encountered in the construction of these works, as they had to be carried out without impeding the traffic in the harbour. They were completed in December 1851, so far as the dock was concerned. An additional half-tide basin and lock, at the upper end of the dock, was commenced in 1856, and completed in 1861.

An immediate effect was felt in the increased tonnage of the shipping, and in the superior description and size of the vessels frequenting the port.

In the year 1853, Mr. Armstrong (now Sir William Armstrong) was consulted, and in 1856 hydraulic power was first applied to work the existing hand gearing of the lock by a system of shafting, which has since been superseded by more perfect adaptation of the power, but the machinery, nevertheless, has worked without failure up to the present time.

As far back as the year 1846, attention was directed to the foreshore of the sea, westward of the harbour entrance, as a site for floating dock accommodation, and His Grace the late Duke of Beaufort consulted Mr. Brunel on the subject, and in his report of October 1846, whilst strongly condemning a project again revived for converting the river into a float, he strongly recommended the construction of a dock on the foreshore, on the site of the present South Dock. An Act was obtained in 1847 for its construction, and in 1850 the works were commenced. These docks are constructed in great part seaward of the original high-water mark, and the geological features of the strata, exposed in the excavation, were somewhat of an extraordinary character, consisting:—

1. Of made ground, ranging in depth from 20 to 26 feet, composed of gravel and boulder stones, which must have been transported from a considerable distance, by the action of river floods, probably from the neighbourhood of Llandore.
2. Peat, with leaves, trees, &c., 2 feet.
3. Blue or marine clay, 8 feet 6 inches, containing shells imbedded in it, 'Scrobicularia piperata,' stated to be still living on the coast.
4. Peat, 2 feet 10 inches.
5. Blue marine clay, 4 feet 1 inch.
6. Peat with trees, 3 feet 1 inch, overlying the gravel foundation upon which the works are founded.

At two points the foundations had to be taken to an extraordinary depth in the lower peat, arising from the depression of the gravel at those points, apparently ancient river beds, and in the peat were found various trees supposed to be the remains of an ancient forest. Antlers of the red deer were also found in this stratum.

The existence of this upper bed of marine clay beneath the made ground indicated that a dock might be constructed on the site with great facility without danger of percolation from the tidal waters, and the result proved the accuracy of this conclusion. The works were commenced in 1854 and completed in 1859. They consist of a trumpet-mouth entrance basin leading to a half-tide basin entrance 70 feet in width, with a depth of water over the cill of 24 feet at H.W.O.S.T., a half-tide basin or outer dock of 4 acres area leading to an entrance lock 300 feet in length and 60 feet in width, with a depth over the inner cill of 22 feet 6 inches, the dock level being kept level with the tide of the day by pumping from the half-tide basin in order to prevent accretion in the dock by the admission of the tidal water heavily charged with detritus.

In 1860 the Great Western Railway Company completed their line into Swansea, together with certain provisions for shipping coal by hydraulic machinery in the North Dock, and in 1863 a railway was completed from Neath to Swansea, by which the great Welsh coal-field was brought into immediate communication with the port, and it became a matter of great importance that this coal should be conveyed to the South Docks for shipment. This involved the construction of two massive opening bridges for a double line of broad gauge railway, one across the New Cut

or river Tawe, with an opening portion of 60 feet span; and another across the lock of the North Dock of 72 feet span, both of which were executed by the firm of Sir William Armstrong and Co., and are worked by hydraulic power.

In connection with these works extensive viaducts had to be constructed through the town and along the quay of the South Dock, for the shipment of coal from the high level by hydraulic drops, also constructed by Sir W. Armstrong and Co. These works were all completed about the year 1863, and the immediate result was an increase in the tonnage of the port from the year 1851, the period of the completion of the first or North Dock, from 269,554 tons to 847,823 tons during the past year.

During south-westerly gales it was found that the Western Pier, from its termination being slightly within or landward of that of the Eastern Pier, afforded inadequate protection from those gales, and in consequence a considerable inrun of the sea existed within the Harbour, and the sand also driven coastward during south-westerly winds occasionally blocked up the entrance. In order to remedy these defects, and to form a defined channel over the foreshore to low-water mark, an extension of the Western Pier was decided upon and completed for a length of 1000 feet in 1863, the result being that the inrun of the sea no longer existed, and the entrance channel formed by dredging *pari passu* with the extension of the pier maintained its depth by the prolonged defined direction of the ebbing tidal current.

Subsequently, in 1875, it was determined to further prolong the pier an additional 1000 feet, which was completed in 1877, the effect being a still further increase in the depth of the channel, which has been maintained; so that, at present, instead of 20 feet at spring tides, which existed in 1849, there is now an available depth of about 28 feet, which is conserved by the prolonged and defined action of the outgoing tidal current, aided, to a certain extent, by the river floods.

In consequence of the great increase in the size and number of the shipping frequenting the port, particularly steam vessels, it has been found indispensable to provide an entrance lock of greater size and depth of water over the cill, with an additional extensive dock and spacious quays so as to furnish ample siding accommodation for the shipment of coal and increased facilities generally for the rapid and economical loading and discharging of cargoes. In consequence, the Trustees have entered into a contract for the construction of a dock in Fabian's Bay of $23\frac{1}{4}$ acres area of water space, together with an entrance lock 450 feet in length, and 60 feet in width, with 32 feet of water over the outer cill at H.W.O.S.T.; the dock to be kept (as in the case of the South Dock) above the tide of the day by the surplus water from Port Tennant Canal and other sources discharging into it.

As regards the shipment of coal it is proposed to be conducted on the same system as that at the Alexandra Dock at Newport, viz. by gravitation from the sidings to the hoists both for the loaded and empty waggons, the whole machinery of the dock appliances to be worked by hydraulic power, it having been found possible by this system at a very moderate cost to ship from 150 to 200 tons of coal per hour at each hoist.

In addition to providing this extensive dock accommodation the embanking of the indent termed 'Fabian's Bay' within the Eastern Pier will, it is anticipated, as in other well-known cases, tend to accelerate the tidal flow into the upper reaches of the river, and give a better direction and greater force to the ebbing tidal current for the future maintenance of the entrance channel at present in progress of being further deepened by dredging.

These various works are now in course of construction, and in conclusion I have to state that it will afford me pleasure to conduct you over them and to explain in detail their features, and those of the works executed during past years.

The following Papers were read:—

1. *On the Bute Docks, Cardiff.* *By* J. McConnochie, *M.Inst.C.E.*

The construction of the Bute Docks at Cardiff, and the consequent rapid growth of the town, are due to the remarkable foresight and public spirit of the late

Marquess of Bute, who, in the year 1830, finding the great mineral wealth of the adjoining district of South Wales locked up by the want of railway conveyance to the sea-coast, and proper means of shipment, resolved upon the construction of a dock on the foreshore at Cardiff, the only accommodation then existing for vessels being the Glamorganshire Canal, with a limited capacity available only for vessels up to 200 tons.

The original design of the engineer, Mr. Green of Exeter, was to place the entrance gates on the foreshore at a point near the end of the present low-water pier, and to construct a ship canal across the foreshore to the intended dock on the mainland. The expense and difficulty of constructing such a work at that time led to a modification, and it was ultimately decided, under the advice of the late Sir William Cubitt, to cut an open tidal channel across the foreshore to the mainland, and then construct an entrance basin communicating with the dock by means of a lock.

This dock, now called the 'Bute West Dock,' was, with its sea approach, completed in 1839, at a cost of about 400,000*l.*, an expenditure which even then displayed the public spirit of the late Marquess of Bute, when the total import and export trade amounted to less than 7000 tons per annum, as compared with 5,000,000 tons per annum at the present time, showing an increase of over 700 times.

The tidal water of this part of the Bristol Channel contains a very large quantity of mud in suspension, which would have involved a heavy expenditure for dredging the deposit if the tidal water had been impounded in the dock. This consideration led the engineer to fix the level of the dock water at several feet above the high-water level of the Channel, and to supply the dock with fresh water from the river Taff. The water is drawn from the river for this purpose about two miles inland, and the feeder passes through the town, and delivers the fresh water at the north end of the dock. The entrance channel across the foreshore is three-quarters of a mile long and about 200 feet wide. The basin is 300 feet long and 200 feet wide, with an entrance of 47 feet wide from the sea; the lock between the basin and the dock is 152 feet long and 36 feet wide. The dock is 4000 feet long and 200 feet wide, with 19 feet depth of water for a length of about 1500 feet, and 15 feet for the remaining length of about 2500 feet.

The depth of water on the sill of the entrance gates is 28 ft. 9 in. at high water of ordinary spring tides, and the gates are opened only for one hour before, and about two hours after high water. The gates are constructed of timber. The water area of the dock and basin amounts to 20 acres.

So great and rapid was the increase of traffic after the opening of the Bute West Dock, that in 1851 it was decided by the trustees of the Marquess of Bute to construct a new dock of larger capacity, now called the 'Bute East Dock.' This dock has a sea-basin 380 feet long by 250 feet wide, approached from the entrance channel on the foreshore by a lock 220 feet long by 55 feet wide, having a depth of 31 feet 9 inches on the sill, or 3 feet more than in the West Dock. The inner lock from the sea basin to the dock is 200 feet long by 50 feet wide. The dock is 4300 feet long by 300 feet wide for the first 1000 feet, and 500 feet wide for the remaining 3300 feet. The uniform depth of water is 25 feet, the water-level in this dock being maintained at the same level as in the West Dock, by water drawn from the river Taff. The water area of the East Dock and basin amounts to 45 acres. The lock gates were originally constructed of German and English oak; but having ultimately proved too weak to resist the great pressure of water to which they were subjected, the gates of the outer lock were replaced in 1863 by new gates, constructed of wrought-iron ribs, English oak heel and meeting posts, and Dantzic fir planking. The gates of the inner lock were replaced in 1878 by new gates constructed of wrought-iron ribs, heel and meeting posts with greenheart facings, and Dantzic fir planking on both sides of the lower gates; the upper gates were faced on the dock side with wrought-iron plates, and Dantzic fir planking on the lock side; both upper and lower gates being on the buoyant principle, this construction being rendered necessary by the limited space provided in the masonry for wooden gates, and has proved perfectly satisfactory. A junction canal connects the East and West Docks with the Glamorganshire Canal.

The basin and first portion of the East Dock were opened for traffic in 1855, and the remaining length of the dock was completed in 1859. The East Dock was commenced from the designs of Sir John Rennie and Mr. John Plews, and completed from the designs of Messrs. Walker, Burges, and Cooper.

New Basin.—Notwithstanding this large accession to the dock area of the port, the continued increase of traffic called for further accommodation; and in 1864 application was made to Parliament by the Bute Trustees for powers to construct additional dock accommodation; but it was not until 1866 that an Act was obtained for the construction of an additional basin, which has been completed from the author's designs, and was opened for traffic in 1874. This basin is intended as a preliminary to an additional dock of 54 acres area, for which Parliamentary powers have been obtained; and while serving the new dock, it also relieves and facilitates the working of the traffic of the Bute East Dock.

The New Basin is 1000 feet long by 525 feet wide, having a water area of 12 acres. It is entered from the channel on the foreshore, which has been widened for this purpose by a sea-lock 350 feet long and 80 feet wide, having 35 feet 9 inches depth of water on the sill. A junction lock 370 feet long, with gates 60 feet wide, connects this basin with the East Dock. The chamber of the lock is 120 feet wide, so as to pass three or four vessels at the same time.

The existing dock accommodation provided by the Marquess of Bute and his Trustees now amounts to 77 acres, and the Parliamentary powers recently obtained will enable the Trustees still further to increase this accommodation by 54 acres to meet the growing requirements of the port.

The gates of the Sea Lock of the New Basin are 80 feet wide, and are believed to be the largest gates hitherto constructed. They are of wrought iron, on the buoyant principle, with skin plates, diaphragms, and lattice ribs, and with greenheart heel posts, meeting posts, and sills. Each leaf of these gates weighs 145 tons. They were constructed by Sir William Armstrong & Co., the arrangement of lattice ribs being adopted at the suggestion of Sir William Armstrong, as affording more convenient access to the interior for examination and repair, and also diminishing the weight in comparison with solid plate ribs.

The gates of the Junction Lock between the New Basin and the East Dock are 60 feet wide, and are of wrought iron, similar in design to the gates of the Sea Lock, but with solid plate ribs in place of lattice ribs. They were constructed by Messrs. Maudsley Brothers, of the Bute Iron Works, Cardiff. The lock gates, capstans, bridges, and sluices connected with the New Basin are worked by hydraulic machinery; those at the East and West Docks were arranged for hand power, and are still so worked.

The provisions for the examination and repair of vessels entering the port consist of four graving docks—one 200 feet long, entered from the West Dock; one 400 feet long, entered from the East Dock, both the property of Messrs. C. Hill & Sons, on ground leased to them by the Bute Trustees. The third graving dock, 320 feet long, is outside the entrance of the docks, and is the property of Messrs. Gunn & Co. The fourth graving dock, 600 feet long, with an entrance 60 feet wide, has been constructed by the Bute Trustees, and is entered from the New Basin. It is available for use by the public on payment of dockage rates, as at Liverpool. A gridiron, 350 feet long, has also been constructed by the Bute Trustees on the east side of the channel outside the entrance of the docks.

A low-water pier, 1400 feet long and 34 feet wide, was constructed in 1868. The pier-head is provided with a floating pontoon or landing-stage, and the minimum depth of water is 6 feet at low-water spring tides. A railway is laid along the pier, and also a carriage-way, and a vertical lift and 10-ton hydraulic crane are fixed at the pier-head, together with suitable waiting rooms and conveniences. Prior to the construction of this pier all communication with vessels in the roads was cut off for a considerable time at each low water, which caused much inconvenience.

The principal portion of the trade carried on in the Bute Docks is the export of coal and iron, which amounted to four million tons in the year 1879. The import of iron ore, timber, and general merchandise amounted in the same year to one

million tons. The consequence of the preponderance of exports is that ships arrive at the port mostly in ballast, and special provision is required to be made for the discharge of this ballast. There are four steam and two hydraulic cranes for this purpose, each capable of discharging 50 tons per hour. These cranes discharge the ballast into railway waggons, which are conveyed a distance of about two miles to land where the ballast is deposited.

To provide for the safe removal of the vessels from the ballast quay to the loading berth, after the discharge of the ballast, wooden booms, weighing from 5 to 20 tons each, are now fixed, one on each side of the ship, to keep it steady. The growing use of water ballast for steamers engaged in the coal trade at the present day has greatly expedited the preparation of vessels for receiving their outward cargoes.

The coal traffic of the West Dock is supplied exclusively by the Taff Vale Railway from Merthyr, Dowlais, and the Aberdare and Rhondda Valleys. The traffic to the East Dock is supplied jointly by the Taff Vale, Rhymney, and Great Western Railways, the last of which is the means of communication with the great coal-field now being opened in the centre of Glamorganshire, in the Ogmore district. The London and North-Western and Midland Railways have also access to the docks by their connection with the above railways.

A very large extent of siding accommodation is required for working the coal shipping trade; for, owing to the fluctuations of the trade, loaded waggons have to be stored in the sidings at times when the supply exceeds the demand. The extent ef sidings provided and maintained by the Bute Trustees in connection with the docks amounts to fifty miles in length (of single line), the whole of which is at times fully occupied.

Coal Tips.—The number of tips for loading coal at the Bute Docks is as follows, viz.:—

13	balance	tips	at the	West Dock.
14	„	„	„	East Dock.
6	hydraulic	„	„	East Dock and Entrance Basin.
1	„	„	„	Entrance Channel for loading in the tideway.
8	„	„	„	Roath Basin.
42	total number of tips.			

Anti-breakage Cranes.—As the South Wales coal is of a very brittle character, it is found necessary to take special precautions for reducing the loss by breakage that occurs in discharging the coal waggons into the ship's hold, and for this purpose anti-breakage cranes are applied to each coal tip with great success. A square iron bucket, holding one ton of coal, and made hopper-shaped, with a hinged flap for discharging at the bottom, is suspended from an independent light 'jib' crane, fixed at one side of the tip frame, and having, in the hydraulic tips, hydraulic lifting and turning motions. In commencing the loading of a ship, this bucket is filled from the shoot, and then lowered to the bottom of the hold and emptied, the process being repeated until a conical heap of coal is formed high enough to reach nearly to the hatchway; the shoot is then allowed to discharge freely, and delivers close down upon the heap, so as to prevent any breakage of the coal by the vertical drop. These cranes are also used with advantage for discharging ballast or ordinary merchandise, and for filling into waggons the small coal that passes through the screens in the shoots on to the ship's deck.

Notwithstanding all these precautions, the proportion of slack that is found in the coal when the ships are discharged at the end of the voyage is generally too large to be satisfactory, and the author considers that this is due to the want of care in trimming the coal in the ship's hold, in which process great breakage of coal is caused by the carelessness of the men. This has been practically tested at the Bute Docks, by loading a vessel with coal by means of wheelbarrows filled direct from the waggon and lowered into the hold, and then wheeled at once to the far end of the hold, so as to avoid any subsequent trimming; the result was that, though some extra cost of loading was incurred, the coal was delivered in such exceptionally good condition that the extra cost was much more than covered by the reduction in the loss from slack.

2. *On the Temperature of Town Water-supplies.* *By* BALDWIN LATHAM, *C.E., M.Inst.C.E., F.G.S., F.M.S., &c.*

In this paper the author pointed out that summer diarrhœa and cholera became prevalent when the water-supply of a district arrived at a temperature exceeding 62° Fahrenheit, and he showed that it was the changes which took place in water when at a high temperature that induced the diseases referred to, and not atmospheric changes; in corroboration of which he referred to districts in which the water was invariably cold in summer, and which consequently were not subject to epidemics of diarrhœa. Moreover, in districts in which the supply, when distributed through water mains, was from a well which was naturally cold at its source, as, for example, in the district supplied by the Kent Waterworks Co., when compared with the districts in London supplied from the river Thames, it was found that in the Kent district, the source of supply being so much colder at its source than the Thames supply in summer, the ground required a higher degree of temperature to raise the temperature of the Kent water to a dangerous point, and thus the incidence of the disease in the districts supplied with Kent water fell later than in those supplied with Thames water. If the cause of the disease were due to atmospheric temperature, the incidence should have been identical in both districts. The author further pointed out that great changes in the temperature of water were due to the temperature of the ground at the depths at which the mains were laid; that the temperature of the ground might be made use of in a special apparatus patented by Professor J. T. Way and himself, by which water was made to descend to a depth of about 25 feet, by means of a vertical tube driven or screwed into the ground, so that the temperature of water required for dietetic purposes was rendered nearly uniform throughout the year. A greater range than 5° would not practically occur in such a tube; whereas in Croydon, where there was a constant water-supply, and where the water was of nearly uniform temperature in the wells before passing into the mains, the range in the temperature had been 27·6°, and a cistern supply of the same water gave a range of 38·7°. By keeping the temperature of the water between the limits of 49° and 54°, by the use of the apparatus referred to, it was explained by the author that summer diarrhœa could, in a great measure, be prevented.[1]

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3. *On Spontaneous Combustion of Coals in Ships.* *By* JAMES BAMFIELD.

SATURDAY, AUGUST 28.

The Section met and adjourned.

MONDAY, AUGUST 30.

The following Reports and Papers were read:—

1. *Report of the Committee on Tidal Observations in the English Channel.* See Reports, p. 390.

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2. *Report of the Committee on Patent Legislation.* See Reports, p. 318.

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[1] The paper appeared at length in the *Builder* of September 11, 1880, and in the *Journal of the Society of Arts* of September 17, 1880.

CORNISH ENGINE

Fig. 1

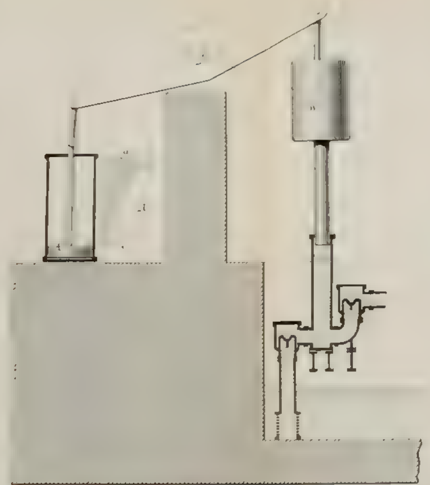


Fig 2

COMPOUND DIFFERENTIAL ENGINE

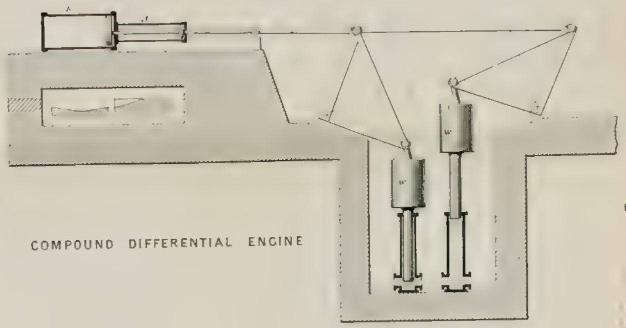
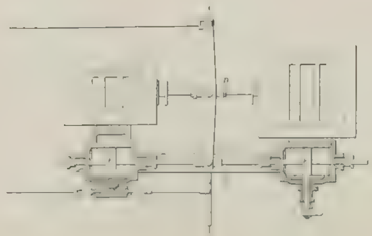
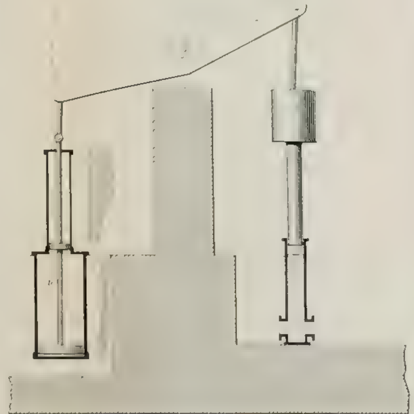


Fig 3



COMPOUND CORNISH ENGINE

Fig. 4



Illustrating Mr Davey's paper on the Expansion of Steam in Non-rotative pumping engines

Fig. 1

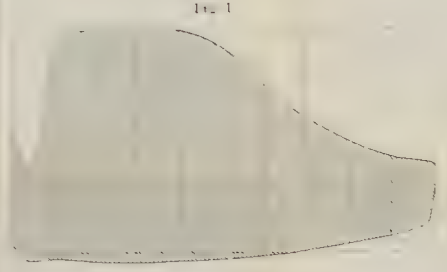


Fig. 2. COMPOUND DIFFERERENTIAL 30" & 60" CYLS

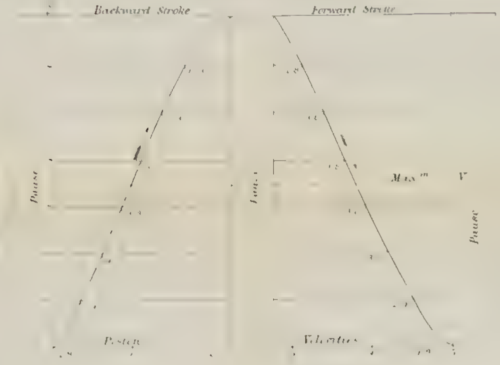
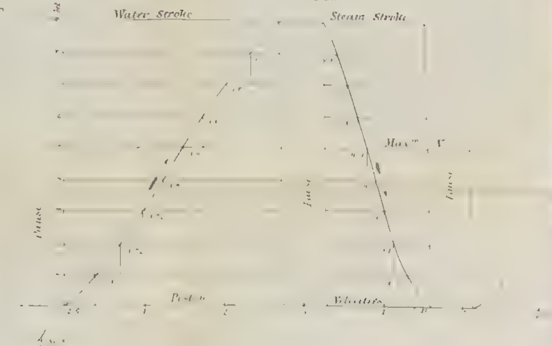


Fig. 3. CORNISH 60" CYLINDER



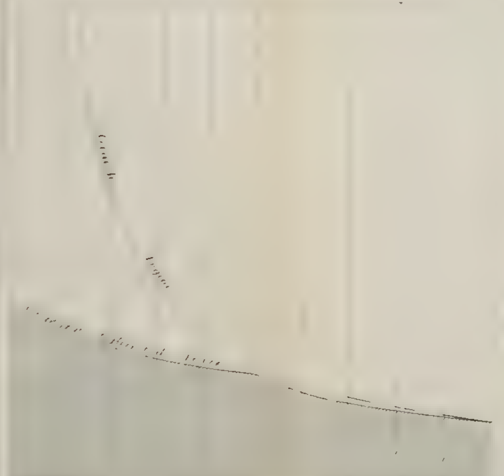


Fig. 4.

Relative strokes of Cornish & Compound Differential Engines working with an eight fold expansion

Fig. 5

Relative Piston-velocities of Cornish & Compound Differential Engines each making 12 strokes per minute. The Cornish engine making an effective pumping speed of 100 feet per minute & the Differential 160 ft per minute

Illustrating Mr. Davey's paper on the Expansion of Steam in Non-rotative pumping engines

3. *On the Anthracite Coal and Coal-field of South Wales.* By C. H. Perkins. See Reports, p. 220.

4. *On the Expansion of Steam in Non-Rotative Pumping Engines.* By Henry Davey, *M.Inst.C.E., F.G.S.*

(Plates XII., XIII.)

The Cornish Engine (Plate XII., fig. 1) has a piston, A, attached to one end of a massive beam, the outer end of which is attached to the plunger of the pump. On the plunger is placed a heavy weight, W. When the piston is at the top of its stroke steam is admitted on the upper surface of the piston of sufficient tension to impart to it a high initial velocity. The shaded diagram A′ represents a steam diagram, and the point b the point at which the pressure corresponds with the average pressure. The area $a, b, c, d,$ represents the work accumulated in the moving mass W, whilst the piston is moving through the space $a, b,$ and which is given out again whilst it is still moving through the distance b, c. The energy of the mass at the time of its maximum velocity is expressed in foot-pounds by $\frac{\mathrm{W}\mathrm{V}^2}{2g}$. Putting R for the resistance of the pump, or, as it is usually termed, the 'water load,' and making $\mathrm{R} = \mathrm{W}$, and F = the number of foot-lbs. represented by the area $a, b, c, d,$ we have $\mathrm{F} = \frac{\mathrm{W}\mathrm{V}^2}{64{\cdot}4}$ and $\mathrm{V} = \sqrt{\frac{\mathrm{F}\ 64{\cdot}4}{\mathrm{W}}}$. In the example—an eightfold expansion—$\mathrm{V} = 14{\cdot}1$ feet per second, a velocity far too great for safe working.

The Compound Differential Engine (Plate XII., fig. 2) is an engine in which expansion can be carried to a greater extent with increased safety. The steam is first expanded to a moderate extent in the cylinder A, and then further expanded on the return stroke in the cylinder B. The engine is double-acting, and has double the power of the Cornish engine. The weights W W bear the same relation to the water columns as W does in the Cornish engine, but as there are in this case two weights the mass is equal to twice the water-load.

$$\mathrm{F}' = \frac{2\,\mathrm{W}\mathrm{V}^2}{64{\cdot}4} \text{ and } \mathrm{V} = \sqrt{\frac{\mathrm{F}'\ 64{\cdot}4}{2\,\mathrm{W}}}$$

Assuming, as in the former examples, an eightfold expansion, produced by cutting off the steam at half-stroke in the first cylinder, and expanding that steam into the second cylinder of four times the capacity of the first, the value of $\mathrm{F} = 58$ and $\mathrm{V} = \sqrt{\frac{\mathrm{F}'\ 64{\cdot}4}{2\,\mathrm{W}}} = 6{\cdot}8.$

The value of V would then be:—

For the Cornish Engine $\mathrm{V} = 14{\cdot}1$ feet per second.
For the Compound Engine $\mathrm{V} = 6{\cdot}8$ " "

In practice the comparison is still more favourable to the Compound Engine because of the 'gap' in the diagrams.

The author has constructed a velocity indicator, by means of which he has been enabled to take diagrams showing at a glance the velocities in different parts of the stroke. The diagrams (Plate XIII., fig. 2 and 3) were taken by this instrument. From those, and from steam indicator diagrams taken in connection with them, he has been enabled to form the comparison shown in the following table:—

	Initial Pressure	Ratio of Expansion	Average Pressure	Maximum Piston Velocities in ft. per minute	Relative strains on Engine	Effective Piston speed
	lbs.		lbs.			
Cornish Engine	31	3	16	600	3·6	100
	45	4·5	19	500	4·5	80
Compound Differential Engine	43	6·25	13	228	1·4	168
	80	8	24	220	1·37	150

In the diagrams (Plate XIII., figs. 2 and 3) the abscissæ of the curves represent the spaces passed over by the piston, and the corresponding ordinates the times in which those spaces were described.

The Differential Engine received its name because of its peculiar valve-gear—a gear which automatically effects the distribution of steam by the differential motion produced in combining the motion of the engine-piston with that of a uniformly moving subsidiary piston.

In Plate XII., fig. 3, D is the differential lever, and C the connection to the engine valves. The point R is attached to the subsidiary piston E. The motions of the points R and C are opposite in direction, and when the motions are equal, there is no motion of the point D. When the motion of E is quicker than that of C, the valves are being opened—this occurs at the beginning of the stroke; but as soon as the engine motion C becomes quicker than that of the subsidiary piston E, the valves are being closed. The initial velocity of the engine-piston varies according to the resistance it has to overcome, and the resistance therefore determines the distribution of the steam.

The Differential Engine is double-acting, and the weights W W, Plate XII. fig. 2, support each other, and cannot move except when moved by the engine. Should there be a vacant space in the pump at the commencement of the stroke, the engine would have no resistance to encounter except its own inertia and friction, and would move off very readily on the opening of the steam valve, so much so that its initial motion would be greater than that of the subsidiary engine, and the steam valve would be closed again; but immediately the plunger came in contact with the water, the full load would be upon the engine, and a halt would be produced until the subsidiary engine had gained a lead sufficient to have fully opened the steam valve. Plate XIII., fig. 1, is a steam diagram taken under the conditions just described. This element of safety is most important. Referring to the Cornish Engine, Plate XII., fig. 1, the more the steam is expanded in the cylinder, the greater the initial velocity of the plunger, and the more difficult it is for the water to follow up the plunger closely, and the greater the unsupported weight at the end of the stroke. With an eightfold expansion, the plunger would have an initial velocity of 600 feet per minute, and at the end of the stroke the steam-pressure would only support one-third of the weight W. Should there be a vacant space in the pump, the plunger would fall back with a great shock. This is one of the greatest sources of accident in the Cornish Engine. All the early compound engines were single-acting, that is to say, they were Compound Cornish Engines, and in addition to possessing defects in principle and construction, were very cumbersome and costly for a given power.

Plate XII., fig. 4, illustrates Sims's engine, which was a development of Trevethick's Pole Engine.

Plate XIII., figs. 4 and 5 give respectively the relative strains and velocities in the two engines.

As a question of weight and first cost for a given power, the following is a comparison of the three systems of engines described in the paper:—

	Power.	Weight.	Cost.
The Compound Cornish Engine .	1	100	100 per cent.
The Single Cylinder " " .	1	70	70 "
The Compound Differential " .	1	45	50 "

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5. *Project for a Channel Railway.*[1] *By* Bradford Leslie, *M.Inst.C.E., Agent and Chief Engineer, East Indian Railway.*

This was a pamphlet submitted by Mr. Ernest Benedict, M.Inst.C.E., M.I.E. & S. Scotland, accompanied by two drawings, and describing a project for establishing railway communication between France and England in the neighbourhood of Calais and Dover. The author proposes to lay a single line of rails within a straight cylindrical steel tube, 16 feet in diameter and $2\frac{1}{2}$ inches thick, smooth outside and

[1] Pamphlet printed at the Stanhope Press, Calcutta.

properly stiffened within. This tube is to be ballasted, so as to make it weigh $1\frac{1}{4}$ ton to the foot-run less than the water displaced, and is to be held down to within 35 feet of the lowest water level by two 3-in. chains passed over the tube, and attached to caissons weighing 500 tons each, and sunk a sufficient distance each side of the centre line to give the requisite angle to the four parts of the chain.

These moorings will occur at every 250 feet along the tube, and will be at such an angle and so rigid that the tide will not affect them.

The passage of trains through the tube will relieve the chains of part of the strain on them.

Ventilating shafts to be provided if found necessary, to act as block-signal stations, and to be protected by light-ships moored on either side.

The shore ends of the tube are to be laid in channels dredged and excavated to receive them, and afterwards filled with concrete.

The ends are to be laid in these channels on the hottest day that can be conveniently chosen, and angle-iron rings projecting from the tube, and held firm by the concrete, will prevent any movement from the expansion or contraction of the tube.

The tube to be commenced in the centre, and to be gradually submerged and anchored as the work proceeds. The two ends during construction will rest on pontoons, whereon the work of adding to the tube will be carried on above water, the tube being flexible enough to allow of this being done.

The time required for constructing the tube is estimated at three years, and the cost at eight millions sterling. The working expenses would probably not exceed 20 per cent. of the gross receipts. Twenty-seven trains a day in each direction, at 1*l.* a train mile, would yield 5 per cent.; and three times this number of trains could be worked through the tube in the twenty-four hours.

6. *On Combined Elliptical, Parallel, and Angular Motion.* *By* George Fawcus.

7. *On the Shakespear Safety Lamp.* *By* Colonel Shakespear.

TUESDAY, AUGUST 31.

The following Papers were read:—

1. *On the Loading of Ships.* *By* W. E. Hall.

2. *On the Steering of Ships.* *By* Professor Osborne Reynolds, *F.R.S.*

I have received an important communication from the Admiralty, upon the steering qualities and turning powers of H.M.S. *Minotaur* and *Defence.* As the experiments therein described were made in accordance with the request of the Committee of the British Association upon the Steering of Ships, and as the results obtained are very definite and important, I think it desirable that they should be placed upon record. I therefore append them to this notice. (See Tables, pp. 700–702.)

Admiralty, S.W.,
19*th September*, 1879.

Sir,

I am commanded by my Lords Commissioners of the Admiralty to forward to you, herewith, for your information, with reference to my letter of the 30th April, 1877, S. $\frac{4136}{1903}$, the accompanying copy of a letter, dated the 31st July

TRIAL OF STEERING QUALITIES OR TURNING POWERS OF SCREW SHIPS.

GENERAL MEMO., Feb. 14, 1879.
H.M.S. 'MINOTAUR,' Feb. 14, 1879.

Tonnage, 10,627 (6621). Length, 410 ft. Beam, 59 ft. $3\frac{1}{2}$ in. I. H. P. 6702. Fitted with Hirsch's 4-bladed left-handed propeller.
Diameter, 24 ft. $3\frac{1}{2}$ in. Pitch, 27 ft. $0\frac{3}{16}$ in. Immersion, 1 ft. $9\frac{1}{2}$ in. Draught of water—forward, 27 ft. 2 in.; aft, 26 ft. 10 in. Max. speed, 14 knots.
Speed at trials, 8·2 knots. Revolutions of engines, 38 per minute. Revolutions of engines, 55 per minute.

No. of Trial corresponding to British Association	NATURE OF TRIAL	Experiments in each case to be distinguished by letters	Engines	Helm	Wind	RESULTS					REMARKS
			Time required to stop and reverse	Direction and time required to place it there	Force and direction relative to ship	Angle and direction ship's head first went	Time taken going ditto	Time ship's head returned to object	Time from first order till way was stopped	Angle and direction of ship's head when way was stopped	
I.	Ship going full speed ahead, the screw suddenly reversed and the helm put hard over.	a	Sec. 17	Deg. 39 Port Sec. 23	Starboard Beam Force 1	Starbrd. Deg. $3\frac{1}{2}$	Sec. 47	Not taken	Min. 1 Sec. 17	Not taken	The ship was steered for mark on island 8 miles off. Angles taken by sextant.
		b	13	39 „ 19		„ $7\frac{1}{2}$	57	Min. 1 Sec. 39	2 50	20° to Port	
		c	13	$39\frac{1}{8}$ „ 21		„ $1\frac{1}{2}$	33	0 42	2 23	37° „	
II.	The same repeated with helm set in the opposite direction.	a	Sec. 23	Deg. $32\frac{1}{4}$ Starb. Sec. 26	Starboard Beam Force 1	Port Deg. $5\frac{1}{2}$	M. 1 S. 8	Min. 2 Sec. 8	Min. 2 Sec. 30	Not taken	Stern way was never got on the ship, but in all cases the way was completely stopped.
		b	14	$33\frac{1}{8}$ „ 17		„ $\frac{1}{2}$	1 30	Not taken	2 21	$32\frac{1}{2}$° to Stb.	
		c	10	33 „ 16		„ $3\frac{1}{2}$	1 40	1 6	2 35	10° „	
III.	The ship going fast astern, the screw suddenly started to drive her ahead, and the helm put hard over as in Trial I.										
IV.	Trial III. repeated with the helm in the opposite direction.										
V.	Ship going full speed ahead, with the helm amidships.	a		Amidships	Starboard Beam Force 1	Port 17°	1 min.				
		b		„		„ 51°	1 „				
VI.	Ship going full speed ahead, then the screw reversed, with the helm amidships.	a	14 sec.	Amidships	Starboard Beam Force 1	Port 50°	1 min.				

(Signed) HARRY H. RAWSON, CAPTAIN.

TRIAL OF STEERING QUALITIES.

February 14, 1879.

Tonnage, 3720. Length, 280 ft. Beam, 54½ ft. I. H. P., 1902·5

Fitted with Griffiths's two-bladed left-handed propeller. Diameter, 18 ft. Pitch, 21 ft.

Immersion, 6 ft. Draught of water—forward, 25 ft.; aft, 26½ ft. Speed at trials, 8 knots.

{ Maximum speed, 8·5 knots.
{ Revolutions of engines, 63 per minute.
Revolutions of engines, 61 per minute.

No. of Trial corresponding to British Association	NATURE OF TRIAL.	Experiments in each case to be distinguished by letters	Engines: Time required to stop or reverse (seconds) Stop	Rev'rse	Helm: Direction and time required to place it there (Trns. Deg. Sec.)	Wind: Force and direction relative to ship	RESULTS: Angle and direction ship's head went first	Time taken going ditto (Min. Sec.)	Time ship's head returned to object	Time from first order till way was stopped (Min. Sec.)	Angle and direction of ship's head when way was stopped	REMARKS
I.	Ship going full speed ahead, the screw suddenly reversed and the helm put hard over.	A B C D	20 15 14 15	55 55 54 57	Port 3½=25 in 40 " 3½=25 " 35 " 3½=25 " 25 " 3 =22 " 23	Light air Light air ahead	6¾ points starboard ¼ " port ¼ " starboard ¾ " "	2 20 0 55 1 45 1 50	Nil Nil Not timed Not timed	3 30 3 45 3 30 3 25	5½ points starboard from time engines reversed to way stopped head went to port 1¼ points. 4½ points port 5 " " 3¼ " "	A. Helm put over when engines were stopped B C D do. do. when engines were astern
II.	The same repeated with helm set in opposite direction.	A B C	14 17 13	38 43 58	Starbd. 3½=25 in 23 " 3½=25 " 28 " 3½=25 " 28	Calm. 9 points from port bow force 3	¼ point port Very slowly to starbd. Gradually to port	1 25 2 12 3 38	Nil Nil Nil	3 13 2 12 3 38	2¾ points port ¼ " " 1¾ " "	Helm put over when engines went astern do. do. do. wind springing up force 3.
III.	The ship going fast astern, the screw suddenly started to drive her ahead and helm put hard over as in Trial I.	A B C	12 8 10	32 35 40	Port 3½=25 in 25 " 3½=25 " 26 " 3½=25 " 13	11 points 11 " 7 " } from port bow force 3	Gradually to port	2 18 1 26 2 32	Nil Nil Nil	2 18 1 26 2 32	2¼ points port 2½ " " 3 " "	Helm put over when engines went ahead NOTE.—With helm amidships the ship's head swings to port with stern way
IV.	Trial III. repeated with the helm in the opposite direction.	A B C	15 11 13	42 31 38	Starbd. 3½=25 in 20 " 3½=25 " 24 " 3½=25 " 18	Points Bow force 2 from starbd. 3 11 " port 3 3 " " 3	Continually to port when going astern	2 20 1 55 1 57	Nil Nil Nil	2 20 1 55 1 57	5¼ points port 2¾ " " 3¼ " "	Helm put over when engines went ahead
V.	Ship going full speed ahead with the helm amidships.	A B C D E F			Amidships	South. 1 to 2 Starboard quarter	X / Y Nil / ¾ pts. port 1¾ pts. stbd. / 1½ " stbd 2 " / 1⅓ " " 2 " / 1½ " " 1¼ " / 2 " " 1¼ " / 1¾ " "	Minutes X Y 5 5 5 5 5 5 5 5 5 5 5 5	Nil	31 30	X 1½ points starb'd from time engines stopped and reversed to way stopped head went to port 6 points Y 4¾ points starb'd from time (as above) head went to port 3 points in 3min. 30sec.	Ship going ahead 8 knots at commencement of trial Y Time taken from starting
VI.	Ship going full speed ahead, then the screw reversed with the helm amidships.	A B C D E F			Amidships	Calm. o.	7½ points port 13½ " " 13¾ " " 14 " " 13¾ " " 14½ " "	Minutes 5 5 5 5 5 5	1st circle 14 minutes 2nd circle 11 minutes 30 seconds	32 30	89¼ points port, viz. twice round the compass to port and 17¼ points from time engines were stopped to way stopped 4 points to port in 2 min. 30 sec.	First time making a complete circle in 14 minutes Second time 11 minutes 30 seconds

(Signed) R. R. CATOR, CAPTAIN,

H.M.S. MINOTAUR
AT VIGO,
JULY 31, 1879.

SUMMARY OF RESULTS OF TRIALS OF THE STEERING QUALITIES AND TURNING POWERS OF HER MAJESTY'S SCREW SHIPS 'MINOTAUR' AND 'DEFENCE.'

SHIP	No. of Trial	Experiments	DIRECTION SHIP'S HEAD TENDS TO TURN UNDER INFLUENCE OF: Reversed effect of rudder	Screw (left-handed)	Wind	Helm	RESULTS: Head first went to	Angle and direction of ship's head when way was stopped	REMARKS
'Minotaur'	1	*abc*	Port	Port	Nil before commencing to turn	Starboard	Starboard 4·2 deg. in ...... Sec. $45\frac{1}{2}$	$28\frac{1}{2}$ deg. to Port	The ship in this case answers the reversed effect of rudder and action of screw
	2 5 6	*abc* *ab* *a*	Starboard Nil Nil	Port Starboard Port		Port Nil Nil	Port 3·2 deg. in .... 46 Port 34 deg. in .... 60 Port 50 deg. in 60	$11\frac{3}{4}$ deg. to Starboard	Ship acts under reversed effect of rudder It will be seen that the ship goes $1\frac{1}{2}$ times as far to port (due to screw) as in trial 5
'Defence'	1	*a* *b* *c* *d*	Port Port Port Port	Port Port Port Port	Nil before commencing to turn	Starboard Starboard Starboard Starboard	$6\frac{3}{4}$ points Starboard in......140 $\frac{1}{4}$ point Port in .... 55 $\frac{1}{4}$ point Starboard in ......105 $\frac{3}{4}$ point Starboard in 110	$1\frac{1}{4}$ points to Port $4\frac{1}{2}$ points to Port 5 points to Port $3\frac{1}{4}$ points to Port	The final direction of ship's head in all 4 cases is to port, that is, follows the influence of reversed effect of rudder and action of screw as in case of 'Minotaur.'
	2	*a* *b* *c*	Starboard Starboard Starboard	Port Port Port	Nil Port } very slight Port }	Port Port Port	$\frac{1}{4}$ point Port in .... 85 Very slowly to Starboard in 132 Gradually to Port in 218	$2\frac{3}{4}$ points to Port $\frac{1}{4}$ point to Starboard $1\frac{3}{4}$ points to Port	In 2nd case ship is influenced by the reversed effect of rudder, but in the 1st and 3rd by the screw and helm
	3	*a* *b* *c*	Starboard Starboard Starboard	Starboard Starboard Starboard	Port Port Starboard	Port Port Port	Gradually to Port	$2\frac{1}{4}$ points to Port $2\frac{1}{2}$ points to Port 3 points to Port	In these cases ship obeys the influence of rudder
	4	*a* *b* *c*	Port Port Port	Starboard Starboard Starboard	Starboard Port Starboard	Starboard Starboard Starboard	Continually to Port when going astern	$5\frac{1}{4}$ points to Port $2\frac{3}{4}$ points to Port $3\frac{1}{4}$ points to Port	In these cases ship obeys the influence of the reversed effect of rudder. These results of 3 and 4 show that the direction ship's head may turn is uncertain
	5		Nil	Starboard	Starboard at first	Nil	Average rate of $1\frac{1}{2}$ pts. in 5 min.		Two trials were made by reversing the engines with helm amidships with the following results: 1st from time engines stopped and reversed to way stopped, head went to port 6 pts., 2nd to port 3 pts
	6		Nil	Port	Nil	Nil	12·8 pts. in 5 min. (average rate)		Made 2 complete circles to port in 14 min. and $11\frac{1}{2}$ min. respectively

(Signed) JOHN HAY, VICE-ADMIRAL.

last, from Vice-Admiral Lord John Hay, commanding Channel Squadron, enclosing a copy of the tabular statements, forwarded therein, of the Trials of the Steering Qualities and Turning Powers of H.M.S. 'Minatour' and 'Defence.'

I am, Sir, your obedient servant,

ROBERT HALL.

Osborne Reynolds, Esqre.,
The Owens College, Manchester.

S. 8087. '79.

STEERING QUALITIES AND TURNING POWERS OF SCREW SHIPS.

'Minotaur' at Vigo,
31*st July*, '79.

No. 165.

SIR,

With reference to your letter of the 25th April, '77, S. $\frac{4136}{4727}$, addressed to my predecessor, Vice-Admiral Sir Beauchamp P. Seymour, relative to the Steering Qualities and Turning Powers of Screw Ships, I have now the honour to enclose for the information of the Lords Commissioners of the Admiralty the results of experiments that have, under my direction, taken place in H.M. Ships 'Minotaur' and 'Defence,' together with a summary of the same—observing that these experiments, so far as they go, seem to be useful as illustrating the views of the British Association.

I have, &c.,

JOHN HAY,
Vice-Admiral Commanding.

To the Secretary of the Admiralty.

3. *On an improved Sounding Machine. By* Professor Sir W. THOMSON, *M.A., F.R.S.*

[This machine was exhibited on the steamer 'Flying Cloud,' during an excursion trip to the Worm's Head, on September 1. Various soundings were taken with it, and the depths registered (from 12 to 21 fathoms) agreed closely with those marked on the Admiralty Charts.]

4. *On the Incrustation of Steam Boilers. By* W. THOMSON.

INDEX.

[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

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Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

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Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robinson and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface; —J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

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brata;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

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Together with the Transactions of the Sections, the Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the Recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S.

Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, the Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s.*

CONTENTS:—Seventh Report of a Committee appointed to conduct the Co-operation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lieut.-Col. Sabine, on some Points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s.*

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—Dr. J. Percy, Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our Knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and

recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Aryan and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine; —A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn, on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eight Report of Committee on the Growth and Vitality of Seeds; —W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lieut.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector; —Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s.* (Out of Print.)

Contents:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteoro-

logical Observations taken at St. Michael's from the 1st of January, 1840, to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water, and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850, to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53;—James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations;—Dr. John P. Bell, Observations on the Character and Measurements of Degradation of the Yorkshire Coast;—First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued);—Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54;—Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s.*

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55;—Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18s.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage, and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena, Part 1;—Dr. T. Wright, on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15s.

CONTENTS:—A. Cayley, Report on the recent progress of Theoretical Dynamics;—Sixteenth and Final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mimes in Cornwall;—Dr. G. Plarr, de quelques Transformations de la Somme $\Sigma_0^t \frac{a^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$ a étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des facteurs $\alpha\ (\alpha+1)\ (\alpha+2)$ &c. ... $(\alpha+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the Extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—Dr. John P. Hodges, on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Prof. W. A. Miller, on Electro-Chemistry;—John Simpson, Results of Thermometrical Observations made at the *Plover's* Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Prof. James Buckman, Report on the Experimental Plots

in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, the Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20s.

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857, 1858;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connel and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' Paper 'On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;'—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15s.

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to Cultivated Crops;—A. Thomson, of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahagow, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c., &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—

G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren De La Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air:—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Professor H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship Performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15*s.*

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Prof. Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De La Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on

the Physical Aspect of the Moon ;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon ;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee ;—Third Report of the Committee on Steamship Performance ;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours ;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations ;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859 ;—J. Oldham, Continuation of Report on Steam Navigation at Hull ;—Prof. G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland ;—Prof. Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind ;—Colonel Sykes, Report of the Balloon Committee ;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England ;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland ;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities ;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders ;—Report of the Committee on the Law of Patents ;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING at Cambridge, October 1862, *Published at* £1.

CONTENTS :—James Glaisher, Report on Observations of Luminous Meteors, 1861–62 ;—G. B. Airy, on the Strains in the Interior of Beams ;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee ;—Report on Tidal Observations on the Humber ;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences ;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza ;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank ;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine ;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance ;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal ;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connection with Storms and Changes of Weather ;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations ;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal ;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities ;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics ;—Prof. G. G. Stokes, Report on Double Refraction ;—Fourth Report of the Committee on Steamship Performance ;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861 ;—J. Ball, on Thermometric Observations in the Alps ;—J. G. Jeffreys, Report of the Committee for Dredging on the North and East Coasts of Scotland ;—Report of the Committee on Technical and Scientific Evidence in Courts of Law ;—James Glaisher, Account of Eight Balloon Ascents in 1862 ;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s*.

CONTENTS :—Report of the Committee on the Application of Gun-cotton to Warlike Purposes ;—A. Matthiessen, Report on the Chemical Nature of Alloys ;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them ;—J. G. Jeffreys, Report of the Committee appointed for exploring the Coasts of Shetland by means of the Dredge ;—

G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Prof. Airy, Report on Steam Boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published at* 18*s.*

CONTENTS:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on Deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s.*

CONTENTS:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and

Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—A. G. Findlay, on the Bed of the Ocean;—Prof. A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Prof. Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s*.

CONTENTS:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors;—W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the 'Menevian Group,' and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J. Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the Penetration of Iron-clad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s*.

CONTENTS:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea;—Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis, in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867;—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at £1 5s.*

CONTENTS:—Report of the Lunar Committee;—Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the Desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures;—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published at £1 2s.*

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Sea-going qualities of Ships;—Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee;—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Report on the Practicability of establishing a 'Close Time' for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing;—Report on the Rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures;—Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain;—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18*s.*

CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland;—Report on the Sedimentary Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Sea-going Qualities of Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869–70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the Process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s.*

CONTENTS:—Seventh Report on Kent's Cavern;—Fourth Report on Underground Temperature;—Report on Observations of Luminous Meteors, 1870–71;—Fifth Report on the Structure and Classification of the Fossil Crustacea;—Report of the Committee appointed for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Second Provisional Report on the Thermal Conductivity of Metals;—Report on the Rainfall of the British Isles;—Third Report on the British Fossil Corals;—Report on the Heat generated in the Blood during the Process of Arterialization;—Report of the Committee appointed to consider the subject of Physiological Experimentation;—Report on the Physiological Action of Organic Chemical Compounds;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on Steam-Boiler Explosions;—Report on the Treatment and Utilization of Sewage;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine;—Report on the practicability of establishing a 'Close Time' for the protection of Indigenous Animals;—Report on Earthquakes in Scotland;—Report on the best means of providing for a Uniformity of Weights and Measures;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s.*

CONTENTS:—Report on the Gaussian Constants for the Year 1829;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—Eighth Report on Kent's Cavern;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of

Luminous Meteors, 1871–72;—Experiments on the Surface-friction experienced by a Plane moving through Water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer;—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report on the practicability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee appointed to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871;—Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at £1 5s.*

CONTENTS:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the Cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the Existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for Investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of Inquiry into the Method of making Gold-assays;—Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee appointed to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a 'Close Time' for the preservation of Indigenous Animals;—Report on Luminous Meteors;—On the Visibility of the Dark Side of Venus;—Report of the Committee for the Foundation of Zoological Stations in different parts of the World;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light evolved by Fluid or Solid Substances;—On a periodicity of Cyclones and Rainfall in connexion with Sun-spot Periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of the Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science Lectures and Organization;—Second Report on Science Lectures and Organization.

Together with the Transactions of the Sections, Prof. A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at* £1 5*s.*

CONTENTS:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their Derivatives;—Third Report of the Committee for collecting Fossils from localities in North-western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of Inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann River;—Report of the Committee on the Structure and Classification of the Labyrinthodont;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee appointed to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface, &c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists;—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. John Tyndall's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIFTH MEETING, at Bristol, August 1875, *Published at* £1 5*s.*

CONTENTS:—Eleventh Report on Kent's Cavern;—Seventh Report on Underground Temperature;—Report on the Zoological Station at Naples;—Report of a Committee appointed to inquire into the Methods employed in the Estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea;—Second Report on the Thermal Conductivities of certain Rocks;—Preliminary Report of the Committee for extending the Observations on the Specific Volumes of Liquids;—Sixth Report on Earthquakes in Scotland;—Seventh Report on the Treatment and Utilization of Sewage;—Report of the Committee for furthering the Palestine Explorations;—Third Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.;—Report of the Rainfall Committee;—Report of the Committee for investigating Isomeric Cresols and their Derivatives;—Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—On the Steering of Screw-Steamers;—Second Report of the Committee on Combinations of Capital and Labour;—Report on the Method of making Gold-assays;—Eighth Report on Underground Temperature;—Tides in the River Mersey;—Sixth Report of the Committee on the Structure of Carboniferous Corals;—Report of the Committee appointed to explore the Settle Caves;—On the River Avon (Bristol), its Drainage-Area, &c.;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee appointed to superintend the Publication of the Monthly Reports of the Progress of Chemistry;—Report on Dredging off the Coasts of Durham and North Yorkshire in 1874;—Report on Luminous Meteors;—On the Analytical Forms called Trees;—Report of the Committee on Mathematical

Tables;—Report of the Committee on Mathematical Notation and Printing;—Second Report of the Committee for investigating Intestinal Secretion;—Third Report of the Sub-Wealden Exploration Committee.

Together with the Transactions of the Sections, Sir John Hawkshaw's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SIXTH MEETING, at Glasgow, September 1876, *Published at* £1 5*s*.

CONTENTS:—Twelfth Report on Kent's Cavern;—Report on Improving the Methods of Instruction in Elementary Geometry;—Results of a Comparison of the British-Association Units of Electrical Resistance;—Third Report on the Thermal Conductivities of certain Rocks;—Report of the Committee on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation;—Report of the Committee for testing experimentally Ohm's Law;—Report of the Committee on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report of the Committee on the Effect of Propellers on the Steering of Vessels;—On the Investigation of the Steering Qualities of Ships;—Seventh Report on Earthquakes in Scotland;—Report on the present state of our Knowledge of the Crustacea;—Second Report of the Committee for investigating the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fourth Report of the Committee on the Erratic Blocks of England and Wales, &c.;—Fourth Report of the Committee on the Exploration of the Settle Caves (Victoria Cave);—Report on Observations of Luminous Meteors, 1875–76;—Report on the Rainfall of the British Isles, 1875–76;—Ninth Report on Underground Temperature;—Nitrous Oxide in the Gaseous and Liquid States;—Eighth Report on the Treatment and Utilization of Sewage;—Improved Investigations on the Flow of Water through Orifices, with Objections to the modes of treatment commonly adopted;—Report of the Anthropometric Committee;—On Cyclone and Rainfall Periodicities in connexion with the Sun-spot Periodicity;—Report of the Committee for determining the Mechanical Equivalent of Heat;—Report of the Committee on Tidal Observations;—Third Report of the Committee on the Conditions of Intestinal Secretion and Movement;—Report of the Committee for collecting and suggesting subjects for Chemical Research.

Together with the Transactions of the Sections, Dr. T. Andrews's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SEVENTH MEETING, at Plymouth, August 1877, *Published at* £1 4*s*.

CONTENTS:—Thirteenth Report on Kent's Cavern;—Second and Third Reports on the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products;—Report on the present state of our Knowledge of the Crustacea (Part III.);—Third Report on the Circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England;—Fifth Report on the Erratic Blocks of England, Wales, and Ireland;—Fourth Report on the Thermal Conductivities of certain Rocks;—Report on Observations of Luminous Meteors, 1876–77;—Tenth Report on Underground Temperature;—Report on the Effect of Propellers on the Steering of Vessels;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals;—Report on some Double Compounds of Nickel and Cobalt;—Fifth Report on the Exploration of the Settle Caves (Victoria Cave);—Report on the Datum Level of the Ordnance Survey of Great Britain;—Report on the Zoological Station at Naples;—Report of the Anthropometric Committee;—Report on the Conditions under which Liquid Carbonic Acid exists in Rocks and Minerals.

Together with the Transactions of the Sections, Prof. Allen Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-EIGHTH MEETING, at Dublin, August 1878, *Published at £*1 4*s.*

CONTENTS :—Catalogue of the Oscillation-Frequencies of Solar Rays ;—Report on Mr. Babbage's Analytical Machine ;—Third Report of the Committee for determining the Mechanical Equivalent of Heat ;—Report of the Committee for arranging for the taking of certain Observations in India, and Observations on Atmospheric Electricity at Madeira ;—Report on the commencement of Secular Experiments upon the Elasticity of Wires ;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine ;—Report on the best means for the Development of Light from Coal-Gas ;—Fourteenth Report on Kent's Cavern ;—Report on the Fossils in the North-west Highlands of Scotland ;—Fifth Report on the Thermal Conductivities of certain Rocks ;—Report on the possibility of establishing a 'Close Time' for the Protection of Indigenous Animals ;—Report on the occupation of a Table at the Zoological Station at Naples ;—Report of the Anthropometric Committee ;—Report on Patent Legislation ;—Report on the Use of Steel for Structural Purposes ;—Report on the Geographical Distribution of the Chiroptera ;—Recent Improvements in the Port of Dublin ;—Report on Mathematical Tables ;—Eleventh Report on Underground Temperature ;—Report on the Exploration of the Fermanagh Caves ;—Sixth Report on the Erratic Blocks of England, Wales, and Ireland ;—Report on the present state of our Knowledge of the Crustacea (Part IV.) ;—Report on two Caves in the neighbourhood of Tenby ;—Report on the Stationary Tides in the English Channel and in the North Sea, &c. ;—Second Report on the Datum-level of the Ordnance Survey of Great Britain ;—Report on Instruments for measuring the Speed of Ships ;—Report of Investigations into a Common Measure of Value in Direct Taxation ;—Report on Sunspots and Rainfall ; —Report on Observations of Luminous Meteors ;—Sixth Report on the Exploration of the Settle Caves (Victoria Cave) ;—Report on the Kentish Boring Exploration ;—Fourth Report on the Circulation of Underground Waters in the Jurassic, New Red Sandstone, and Permian Formations, with an Appendix on the Filtration of Water through Triassic Sandstone ;—Report on the Effect of Propellers on the Steering of Vessels.

Together with the Transactions of the Sections, Mr. Spottiswoode's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-NINTH MEETING, at Sheffield, August 1879, *Published at £*1 4*s.*

CONTENTS :—Report on the commencement of Secular Experiments upon the Elasticity of Wires ;—Fourth Report of the Committee for determining the Mechanical Equivalent of Heat ;—Report of the Committee for endeavouring to procure reports on the Progress of the Chief Branches of Mathematics and Physics ;—Twelfth Report on Underground Temperature ;—Report on Mathematical Tables ;—Sixth Report on the Thermal Conductivities of certain Rocks ;—Report on Observations of Atmospheric Electricity at Madeira ;—Report on the Calculation of Tables of the Fundamental Invariants of Algebraic Forms ;—Report on the Calculation of Sun-Heat Coefficients ;—Second Report on the Stationary Tides in the English Channel and in the North Sea, &c. ;—Report on Observations of Luminous Meteors ;—Report on the question of Improvements in Astronomical Clocks ;—Report of the Committee for improving an Instrument for detecting the presence of Fire-damp in Mines ;—Report on the Chemistry of some of the lesser-known Alkaloids, especially Veratria and Bebeerine ;—Seventh Report on the Erratic Blocks of England, Wales, and Ireland ;—Fifteenth Report on Kent's Cavern ;—Report on certain Caves in Borneo ;—Fifth Report on the Circulation of Underground Waters in the Jurassic, Red Sandstone, and Permian Formations of England ;—Report on the Tertiary (Miocene) Flora, &c., of the Basalt of the North of Ireland ;—Report on the possibility of Establishing a 'Close Time' for the Protection of Indigenous Animals ;—Report on the Marine Zoology of Devon and Cornwall ;—Report on the Occupation of a Table at the Zoological Station at Naples ;—Report on Excavations at Portstewart and elsewhere in the North of Ireland ;—Report of the Anthropometric Committee ;—Report on the Investigation of the Natural History of Socotra ;—Report on Instru-

ments for measuring the Speed of Ships;—Third Report on the Datum-level of the Ordnance Survey of Great Britain;—Second Report on Patent Legislation;—On Self-acting Intermittent Siphons and the conditions which determine the commencement of their Action;—On some further Evidence as to the Range of the Palæozoic Rocks beneath the South-east of England;—Hydrography, Past and Present.

Together with the Transactions of the Sections, Prof. Allman's Address, and Recommendations of the Association and its Committees.

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

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OF THE

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1880.

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‡ indicates Subscribers not entitled to the Annual Report.
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Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of Residence should be sent to the Assistant Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Burgess Hill, Sussex.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1863. *ABEL, FREDERICK AUGUSTUS, C.B., F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.
1873. ‡Abernethy, James. Ferry-hill, Aberdeen.
1860. ‡Abernethy, Robert. Ferry-hill, Aberdeen.
1873. *ABNEY, Captain W. de W., R.E., F.R.S., F.R.A.S., F.C.S. 3 St. Alban's-road, Kensington, London, W.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1877. §Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Francis E. Dyke, R.A. Oxford.
1873. **Acland, Rev. H. D. Loughton, Essex.*
ACLAND, HENRY W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.

Year of Election.

1877. *Acland, Theodore Dyke, M.A. 13 Vincent-square, Westminster, S.W.

1860. ‡Acland, Sir Thomas Dyke, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.

Adair, John. 13 Merrion-square North, Dublin.

1872. ‡Adams, A. Leith, M.A., M.B., F.R.S., F.G.S., Professor of Natural History in Queen's College, Cork. 18 Clarendon-gardens, Maida Hill, London, W.

1876. ‡Adams, James. 9 Royal-crescent West, Glasgow.

*Adams, John Couch, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndsean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

1871. ‡Adams, John R. 3 Queen's-gate-terrace, London, S.W.

1879. §Adams, Rev. Thomas, M.A. Clifton Green House, York.

1877. ‡Adams, William. 3 Sussex-terrace, Plymouth.

1869. *Adams, William Grylls, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.

1873. ‡Adams-Acton, John. Margutta House, 103 Marylebone-road, London, N.W.

1879. §§Adamson, Robert, M.A., Professor of Logic and Political Economy in Owens College, Manchester. 60 Parsonage-road, Withington, Manchester.

Adderley, The Right Hon. Sir Charles Bowyer, M.P. Hams-hall, Coleshill, Warwickshire.

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1865. *Adkins, Henry. Northfield, near Birmingham.

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1871. *Ainsworth, John Stirling. The Flosh, Cleator, Carnforth.

Ainsworth, Peter. Smithills Hall, Bolton.

1842. *Ainsworth, Thomas. The Flosh, Cleator, Carnforth.

1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.

1859. ‡Airlie, The Right Hon. the Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.

Airy, Sir George Biddell, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich, S.E.

1871. §Aitken, John, F.R.S.E. Darroch, Falkirk, N.B.

Akroyd, Edward. Bankfield, Halifax.

1862. ‡Alcock, Sir Rutherford, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.

1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.

1872. *Alcock, Thomas, M.D. Oakfield, Sale, Manchester.

*Aldam, William. Frickley Hall, near Doncaster.

Alderson, Sir James, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.

1859. ‡Alexander, General Sir James Edward, K.C.B., K.C.L.S., F.R.S.E., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N.B.

1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.

1858. ‡Alexander, William, M.D. Halifax.

1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.

1867. ‡Alison, George L. C. Dundee.

1859. ‡Allan, Alexander. Scottish Central Railway, Perth.

1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.

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1879. *Allen, Rev. A. J. C. Peterhouse, Cambridge.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
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1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
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1875. *ALSTON, EDWARD R., F.L.S., F.Z.S. 14 Maddox-street, Regent-street, London, W.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1876. ‡Anderson, Alexander. 1 St. James's-place, Hillhead, Glasgow.
1878. ‡Anderson, Beresford. Saint Ville, Killiney.
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1880. §Anderson, Richard. New Malden, Surrey.
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1877. §Angell, John. 81 Ducie-grove, Oxford-street, Manchester.
1859. ‡Angus, John. Town House, Aberdeen.
1878. ‡Anson, Frederick H. 9 Delahay-street, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
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1868. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *ARCHER, Professor THOMAS C., F.R.S.E., Director of the Museum of Science and Art, Edinburgh. West Newington House, Edinburgh.
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1867. *Armitstead, George. Errol Park, Errol, N.B.
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1873. §§Armstrong, Henry E., Ph.D., F.R.S., F.C.S. London Institution, Finsbury-circus, London, E.C.
1878. ‡Armstrong, James. 28A Renfield-street, Glasgow.
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1866. ‡Baillon, L. St. Mary's Gate, Nottingham.

Year of Election.

1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
1873. §Bain, Sir James. 3 Park-terrace, Glasgow.
1865. ‡*Bain, Rev. W. J. Glenlark Villa, Leamington.*
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, EDWARD, J.P. Belgrave Mansions, Grosvenor-gardens, London, S.W.; and St. Ann's Hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. St. John's-road, Buxton.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. Moorland House, Stoke Bishop, near Bristol.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1871. *BALFOUR, FRANCIS MAITLAND, M.A., F.R.S. Trinity College, Cambridge.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡Balfour, Isaac Bayley, D.Sc. 27 Inverleith-row, Edinburgh.
*BALFOUR, JOHN HUTTON, M.A., M.D., LL.D., F.R.S. L. & E., F.L.S. Emeritus Professor of Botany. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 16 Lower Fitzwilliam-street, Dublin.
*BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, S.W.
1866. *BALL, ROBERT STAWELL, M.A., LL.D., F.R.S., F.R.A.S., Andrews Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. The Observatory, Dunsink, Co. Dublin.
1878. §BALL, VALENTINE, M.A., F.G.S. Calcutta. (Care of Messrs. S. H. King & Co., Pall Mall, London, S.W.)
1876. ‡*Ballantyne, James. Southcroft, Rutherglen, Glasgow.*
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1874. *Bangay, Frederick Arthur. Cheadle, Cheshire.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1879. §§Banham, H. French. Mount View, Glossop-road, Sheffield.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Bankhead, Broxton, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A. Bury Hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.

Year of Election.

1879.§§Barker, Elliott. 2 High-street, Sheffield.
1879. *Barker, Rev. Philip C., M.A., LL.B. Rotherham, Yorkshire.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. §Barkly, Sir Henry, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
1878. ‡Barlow, John, M.D. The University, Glasgow.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1857. ‡Barlow, Peter William, F.R.S., F.G.S. 26 Great George-street, Westminster, S.W.
1873. Barlow, W. H., C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868.§§Barnes, Richard H. (Care of Messrs. Collyer, 4 Bedford-row, London, W.C.)
Barnes, Thomas Addison. Brampton Collieries, near Chesterfield.
**Barnett, Richard, M.R.C.S.* 3 *Heath-terrace, Leamington.*
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1861. *Barr, William R., F.G.S. Fernside, Cheadle Hulme, Cheshire.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1872. *Barrett, W. F., F.R.S.E., M.R.I.A., F.C.S., Professor of Physics in the Royal College of Science, Dublin.
1874. ‡Barrington, R. M. Fassaroe, Bray, Co. Wicklow.
1874. §Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Salwarpe End, Droitwich.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡Barry, Rev. Canon, D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
1875. ‡Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
Barstow, Thomas. Garrow Hill, near York.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gasworks, Glasgow.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1873. §Bartley, George C. T. St. Margaret's House, Victoria-street, London, S.W.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, London, N.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡Bastian, H. Charlton, M.D., M.A., F.R.S., F.L.S., Professor of Pathological Anatomy at University College. 20 Queen Anne-street, London, W.
1848. ‡Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1873. *Bateman, Daniel. Low Moor, near Bradford, Yorkshire.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. 9 Hyde Park-gate South, London, W.

Year of Election.

1842. *BATEMAN, JOHN FREDERIC, C.E., F.R.S., F.G.S., F.R.G.S. 16 Great George-street, London, S.W.
1864. ‡BATES, HENRY WALTER, Assist.-Sec. R.G.S., F.L.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡BATH AND WELLS, The Right Rev. Lord ARTHUR HERVEY, Lord Bishop of. The Palace, Wells, Somerset.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, W.
1863. §BAUERMAN, H., F.G.S. 41 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1867. ‡Baxter, The Right Hon. William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 16 London-street, Fenchurch-street, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
Bazley, Thomas Sebastian, M.A. Hatherop Castle, Fairford, Gloucestershire.
1860. *BEALE, LIONEL S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1872. ‡Beanes, Edward, F.C.S. The White House, North Dulwich, Surrey, S.E.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Ash Mount, Rotherham.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.M.S., F.S.S. 18 Piccadilly, London, W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Major George G., F.R.G.S. 16 Holles-street, Cavendish-square, London, W.
1859. *Beck, Joseph, F.R.A.S. 68 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R.S. Clifton, Bristol.
1878. ‡Bedson, P. Phillips, D.Sc. Oak Leigh, Marple, near Stockport.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. ‡Bell, A. P. Royal Exchange, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1880. §Bell, Henry Oswin. 13 Northumberland-terrace, Tynemouth.
1879. §§Bell, Henry S. Kenwood Bank, Sharrow, Sheffield.
1862. *BELL, ISAAC LOWTHIAN, F.R.S., F.C.S., M.I.C.E. Rounton Grange, Northallerton.
1875. §§Bell, James, F.C.S. The Laboratory, Somerset House, London, W.C.

Year of Election.

1871. *Bell, J. Carter, F.C.S. Kersal Clough, Higher Broughton, Manchester.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. §Bell, R. Bruce. 2 Clifton-place, Glasgow.
1863. *Bell, Thomas. Crosby Court, Northallerton.
1867. ‡Bell, Thomas. Belmont, Dundee.
1875. ‡Bell, William. Witford House, Briton Ferry, Glamorganshire.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1864. *Bendyshe, T. 3 Sea-View-terrace, Margate.
1870. ‡Bennett, Alfred W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. §Bennett, Henry. Bedminster, Bristol.
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 5 Tavistock-square, London, W.C.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡Bentham, George, F.R.S., F.R.G.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 2 Portland-place, London, W.
1863. §Bentley, Robert, F.L.S., Professor of Botany in King's College, London. 1 Trebovir-road, South Kensington, London, S.W.
1875. ‡*Beor, Henry R. Scientific Club, Savile-row, London, W.*
1876. ‡Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.
1868. ‡Berkeley, Rev. M. J., M.A., F.R.S., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., F.R.S. St. John's College, Cambridge.
1865. *Bessemer, Sir Henry, F.R.S. Denmark Hill, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1876. *Bettany, G. T., M.A., B.Sc., Lecturer on Botany at Guy's Hospital, London, S.E.
1880. *Bevan, Rev. James Oliver, M.A. 72 Beaufort-road, Edgbaston, Birmingham.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. Shireshead Vicarage, Garstang.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 16 Green Park, Bath.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.
1877. ‡*Binder, W. J., B.A. Barnsley.*
1842. Binney, Edward William, F.R.S., F.G.S. Cheetham Hill, Manchester.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1879. §§Binns, E. Knowles. 216 Heavygate-road, Sheffield.

Year of Election.

Birchall, Edwin, F.L.S. Douglas, Isle of Man.
Birchall, Henry. College House, Bradford.
1880. §Bird, Henry, F.C.S. South Down, near Devonport.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
*Birks, Rev. Thomas Rawson, M.A., Professor of Moral Philosophy in the University of Cambridge. 6 Salisbury-villas, Cambridge.
1841. *Birt, William Radcliff, F.R.A.S. 3 Shrewsbury-villas, Water-lane, Stratford, E.
1871. *Bischof, Gustav. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1877. ‡Blachford, The Right Hon. Lord, K.C.M.G. Cornwood, Ivy-bridge.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. 14 Victoria-road, Kensington, London, W.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
*Blackwall, Rev. John, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1878. §§Blair, Matthew. Oakshaw, Paisley.
1863. ‡Blake, C. Carter, D.Sc. Westminster Hospital School of Medicine, Broad Sanctuary, Westminster, S.W.
1849. *Blake, Henry Wollaston, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1878. §§Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1861. §Blakiston, Matthew, F.R.G.S. 18 Wilton-crescent, London, S.W.
1869. ‡Blanford, W. T., F.R.S., F.G.S., F.R.G.S. Geological Survey of India, Calcutta.
*Blomefield, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1878. ‡*Blood, T. Lloyd.*
1880. §Bloxam, G. W., M.A., F.L.S. 44 Dacre-park, Lee, Kent.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1867. ‡Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1866. §Bogg, Thomas Wemyss. 2 East Ascent, St. Leonard's.
1859. *Bohn, Henry G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham.
1871. ‡Bohn, Mrs. North End House, Twickenham.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.

Year of
Election.

Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. St. John's College, Cambridge.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1876. ‡Booth, William H. Trinity College, Oxford.
1880. §Boothroyd, Samuel. Warley House, Southport.
1861. *Borchardt, Louis, M.D. Barton Arcade, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1876. *Borland, William. 260 West George-street, Glasgow.
1863. ‡*Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.*
1876. *Bosanquet, R. H. M., M.A., F.C.S., F.R.S.A. St. John's College, Oxford.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. *Bottomley, James Thomson, M.A., F.R.S.E., F.C.S. 2 Eton-terrace, Hillhead, Glasgow.
Bottomley, William. 14 Brunswick-gardens, Kensington, London, W.
1876. ‡Bottomley, William, jun. 14 Brunswick-gardens, Kensington, London, W.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1866. §Bourne, Stephen, F.S.S. Abberley, Wallington, Surrey.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. ‡Bower, Anthony. Bowersdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1880. §Bowly, Christopher. Cirencester.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Prince's-park, Liverpool.
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡Boyle, Rev. G. D. Soho House, Handsworth, Birmingham.
1872. *Brabrook, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Cathcart House, Cathcart-road, London, S.W.
1870. ‡Brace, Edmund. 3 Spring-gardens, Kelvinside, Glasgow.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1880. §Bradford, H. Stretton House, Walters-road, Swansea.
1861. *Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1842. *Brady, Sir Antonio, J.P., F.G.S. Maryland Point, Stratford, Essex, E.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡Brady, George S., M.D., F.L.S., Professor of Natural History in

Year of Election.

the College of Physical Science, Newcastle-on-Tyne. 22 Fawcett-street, Sunderland.
1862. §BRADY, HENRY BOWMAN, F.R.S., F.L.S., F.G.S. Hillfield, Gateshead.
1880. *Brady, Rev. Nicholas, M.A. Wennington, Essex.
1875. ‡Bragge, William, F.S.A., F.G.S. Shirle Hill, Birmingham.
1864. §Braham, Philip, F.C.S. 6 George-street, Bath.
1870. ‡Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1879. §§Bramley, Herbert. Claremont-crescent, Sheffield.
1865. §BRAMWELL, FREDERICK J., M.I.C.E., F.R.S. 37 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *BREADALBANE, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1873. ‡Breffit, Edgar. Castleford, near Normanton.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1860. ‡Brett, G. Salford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. §§Briant, T. Hampton Wick, Kingston-on-Thames.
1867. ‡BRIDGMAN, WILLIAM KENCELEY. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. ‡Brierley, Joseph, C.E. New Market-street, Blackburn.
1879. §Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1866. ‡Briggs, Joseph. Barrow-in-Furness.
1863. *BRIGHT, Sir CHARLES TILSTON, C.E., F.G.S., F.R.G.S., F.R.A.S. 20 Bolton-gardens, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. JOHN, M.P. Rochdale, Lancashire.
1868. ‡*Brine, Commander Lindesay. Army and Navy Club, Pall Mall, London, S.W.*
1879. §Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *BRITTAIN, W. H. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, W.C.
1859. *BRODHURST, BERNARD EDWARD, F.R.C.S., F.L.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1834. ‡BRODIE, Rev. JAMES, F.G.S. Monimail, Fifeshire.
1865. ‡BRODIE, Rev. PETER BELLENGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
1878. *Brook, George, F.L.S. Fernbrook, Huddersfield, Yorkshire.
1880. §Brook, G. B. Brynsyfi, Swansea.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1878. ‡Brooke, Sir Victor, Bart., F.L.S. Colebrook, Brookeborough, Co. Fermanagh.
1863. ‡Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.

Year of Election.

1846. *Brooks, Thomas. Cranshaw Hall, Rawtenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1874. ‡Broom, William. 20 Woodlands-terrace, Glasgow.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. §§Brown, David. 93 Abbey-hill, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1870. §BROWN, HORACE T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. *BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1876. ‡Brown, John. Edenderry House, Belfast.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. 26 Guildford-road, Albert-square, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Evesham Lawn, Pittville, Cheltenham.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
1855. ‡Brown, William. 33 Berkeley-terrace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41A New-street, Birmingham.
1879. §§Browne, J. Crichton, M.D., LL.D., F.R.S.E. 7 Cumberland-terrace, Regent's Park, London, N.W.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1875. ‡*Browne, Walter R. Bridgwater.*
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. ‡Browning, John, F.R.A.S. 111 Minories, London, E.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *Brunlees, James, C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., F.R.S. 50 Welbeck-street, London, W.
1878. §Brutton, Joseph. Yeovil.
1877. ‡Bryant, George. 82 Claverton-street, Pimlico, London, S.W.
1875. ‡Bryant, G. Squier. 15 White Ladies'-road, Clifton, Bristol.
1875. ‡Bryant, Miss S. A. The Castle, Denbigh.
1861. ‡Bryce, James. York-place, Higher Broughton, Manchester.
BRYCE, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡BUCCLEUCH AND QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.
1871. §BUCHAN, ALEXANDER, M.A., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.

Year of
Election.

1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Andrew, M.D., Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton-cum-Seacombe, Cheshire.
1871. ‡Buchanan, John Young. 10 Moray-place, Edinburgh.
1864. §Buckle, Rev. George, M.A. The Rectory, Weston-super-Mare.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *Buckman, Professor James, F.L.S., F.G.S. Bradford Abbas, Sherborne, Dorsetshire.
1880. §Buckney, Thomas, F.R.A.S. Little Thurlow, Suffolk.
1869. ‡Bucknill, J. C., M.D., F.R.S. 39 Wimpole-street, London, W.
1851. *Buckton, George Bowdler, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1848. *Budd, James Palmer. Ystalyfera Iron Works, Swansea.
1875. §Budgett, Samuel. Cotham House, Bristol.
1871. ‡Bulloch, Matthew. 11 Park-circus, Glasgow.
1845. *Bunbury, Sir Charles James Fox, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal' Office, New-street, Birmingham.
1863. §Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. Stratton-street, Piccadilly, London, W.
1874. ‡Burdon, Henry, M.D. Clandeboye, Belfast.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1877. ‡Burns, David, C.E. Alston, Carlisle.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1877. ‡Burt, J. Kendall. Kendal.
1874. ‡Burt, Rev. J. T. Broadmoor, Berks.
1866. *Burton, Frederick M., F.G.S. Highfield, Gainsborough.
1879. §§Bury, Percy B. Cambridge.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *Busk, George, F.R.S., F.L.S., F.G.S. 32 Harley-street, Cavendish-square, London, W.
1878. ‡Butcher, J. G., M.A. 22 Collingham-place, London, S.W.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Ph.D. 1 Nottingham-place, London, W.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir T. Fowell, Bart. Warlies, Waltham Abbey, Essex.
1854. ‡Byerley, Isaac, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. 2 Bank-street, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1875. §Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1858. §§Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡Caird, Edward B. 8 Scotland-street, Glasgow.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.

Year of Election.

1855. *Caird, James Tennant. Belleaire, Greenock.
1875. ‡Caldicott, Rev. J. W., D.D. The Grammar School, Bristol.
1877. ‡Caldwell, Miss. 2 Victoria-terrace, Portobello, Edinburgh.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1853. ‡Calver, Captain E. K., R.N., F.R.S. The Grange, Redhill, Surrey.
1876. ‡Cameron, Charles, M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, CHARLES A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, W.C.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S. 13 Cornwall-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
1876. ‡Campbell, James A. 3 Claremont-terrace, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. ‡CAMPBELL, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.
1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana. (Messrs. Ridgway & Sons, 2 Waterloo-place, London, S.W.)
CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F.R.S. 84 St. George's-square, London, S.W.
1876. §Campion, Frank, F.G.S., F.R.G.S. The Mount, Duffield-road, Derby.
1862. *CAMPION, Rev. Dr. WILLIAM M. Queen's College, Cambridge.
1868. *Cann, William. 9 Southernhay, Exeter.
1880. §Capper, Robert. Cwm Donkin, Swansea.
1873. *Carbutt, Edward Hamer, M.P., C.E. St. Ann's, Burley, Leeds, Yorkshire.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
1877. ‡Carkeet, John, C.E. 3 St. Andrew's-place, Plymouth.
1876. ‡Carlile, Thomas. 5 St. James's-terrace, Glasgow.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., Lord Bishop of Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. *Carpenter, P. Herbert, M.A. Eton College, Windsor.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. Winifred House, Pembroke-road, Clifton, Bristol.
1842. **Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, London, S.E.*
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Museum of Science and Art, Dublin.

Year of
Election.

1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 62 Elizabeth-street, Liverpool.
*CARTMELL, Rev. JAMES, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
1878. §§Cartwright, H. S., LL.B. Magherafelt Manor, Co. Derry.
1870. §Cartwright, Joshua, A.I.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. 147 Holborn Bars, London, E.C.
1878. ‡Casey, John, LL.D., F.R.S., M.R.I.A., Professor of Higher Mathematics in the Catholic University of Ireland. 2 Iona-terrace, South Circular-road, Dublin.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Saville Park, Halifax.
Castle, Charles. Clifton, Bristol.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1873. *Cavendish, Lord Frederick, M.P. 21 Carlton House-terrace, London, S.W.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathemathics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1879. §Chadburn, Alfred. Brincliffe Rise, Sheffield.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID, M.P. The Poplars, Herne Hill, London, S.E.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*CHALLIS, Rev. JAMES, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡*Chamberlain, Robert. Catton, Norwich.*
1842. Chambers, George. High Green, Sheffield.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
1877. *Champernowne, Arthur, M.A., F.G.S. Dartington Hall, Totnes, Devon.
*Champney, Henry Nelson. 4 New-street, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1877. §Chapman, T. Algernon, M.D. Burghill, Hereford.
1866. ‡Chapman, William. The Park, Nottingham.

Year of Election.

1871.§§Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. ‡Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast.
1871. ‡*Charles, T. C., M.D. Queen's College, Belfast.*
1836. CHARLESWORTH, EDWARD, F.G.S. 277 Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. Junior Garrick Club, Adelphi-terrace, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1879. *Chesterman, W. Broomsgrove-road, Sheffield.
1879.§§Cheyne, Commander J. P., R.N. 1 Westgate-terrace, West Brompton, London, S.W.
1872. §CHICHESTER, The Right Hon. the Earl of Stanmer House, Lewes.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1875. *Christopher, George, F.C.S. 8 Rectory-grove, Clapham, London, S.W.
1876. *CHRYSTAL, G., B.A., Professor of Mathematics. 15 Chalmers-street, Edinburgh.
1870. §CHURCH, A. H., M.A., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Royston House, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855.§§CLAPHAM, ROBERT CALVERT. Earsdon House, Earsdon, Newcastle-on-Tyne.
1869. ‡Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
1877. *Clark, F. J. 20 Bootham, York.
Clark, G. T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. Glasgow.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.

Year of Election.

1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1861. *Clarke, John Hope. Lark Hill House, Edgeley, Stockport.
1877. ‡Clarke, Professor John W. University of Chicago, Illinois.
1851. ‡CLARKE, JOSHUA, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1850. ‡CLEGHORN, HUGH, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §CLELAND, JOHN, M.D., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
1873. §Cliff, John, F.G.S. Limeburn, Ilkley, near Leeds.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1878.§§Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1866. §CLOSE, THOMAS, F.S.A. St. James's-street, Nottingham.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park Terrace, Glasgow.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. 13 Great Bedford-street, Bath.
1851. *COBBOLD, JOHN CHEVALLIER. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. ‡COBBOLD, T. SPENCER, M.D., F.R.S., F.L.S., Professor of Botany and Helminthology in the Royal Veterinary College, London. 74 Portsdown-road, Maida Hill, London, W.
1864. *Cochrane, James Henry. Monmouth House, Wellington-terrace, Clevedon, Somersetshire.
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1876. ‡Colbourn, E. Rushton. 5 Marchmont-terrace, Hillhead, Glasgow.
1853. ‡Colchester, William, F.G.S. Springfield House, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1879.§§Cole, Skelton. 387 Glossop-road, Sheffield.
1876. ‡Colebrooke, Sir T. E., Bart., M.P., F.R.G.S. 14 South-street, Parklane, London, W.; and Abington House, Abington, N.B.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1878.§§Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 4 Grove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.

Year of Election.

1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. §Collins, J. H., F.G.S. 57 Lemon-street, Truro, Cornwall.
1876. ‡Collins, William. 3 Park-terrace East, Glasgow.
1868. *Colman, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. ‡Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
1874. ‡*Combe, James. Ormiston House, Belfast.*
*Compton, The Ven. Lord Alwyn, Dean of Worcester. The Deanery, Worcester.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1876. ‡Cook, James. 162 North-street, Glasgow.
1876. *Cooke, Conrad W., C.E. 5 Westminster Chambers, London, S.W.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin, F.R.G.S. Mile Ash, Derby.
1850. ‡Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1879. §Cooper, Thomas. Rose Hill, Rotherham, Yorkshire.
1875. ‡Cooper, T. T., F.R.G.S. Care of Messrs. King & Co., Cornhill, London, E.C.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1846. ‡Cooper, William White, F.R.C.S. 19 Berkeley-square, London, W.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology in Queen's College, Cork.
1870. *Corfield, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazenose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Edinburgh. Edinburgh.
1874. *Cotterill, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡Cotton, General Frederick C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡Cotton, William. Pennsylvania, Exeter.
1879. §Cottrill, Gilbert I. Shepton Mallett, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1874. ‡Courtauld, John M. Bocking Bridge, Braintree, Essex.

Year of Election.

1865. ‡Courtauld, Samuel, F.R.A.S. 76 Lancaster-gate, London, W.; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
1876. ‡Cowan, J. B. 159 Bath-street, Glasgow.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Comptons Lea, Horsham.
1873. **Cowans, John. Cranford, Middlesex.*
Cowie, The Very Rev. Benjamin Morgan, M.A., B.D., Dean of Manchester. The Deanery, Manchester.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. 18 Windsor-street, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 50 Newhall-street, Birmingham.
1871. ‡*Cox, William J. 2 Vanburgh-place, Leith.*
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1857. ‡Crampton, Rev. Josiah. Nettlebeds, near Oxford.
1879.§§Crampton, Thomas Russell. 13 Victoria-street, London, S.W.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1876. ‡Crawford, Chalmond, M.P. Ridemon, Crosscar.
1871. **Crawford, William Caldwell, M.A. Hobart House, Eskbank, near Edinburgh.*
1871. ‡Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1879.§§Creswick, Nathaniel. Handsworth Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. George's Vicarage, Kendal.
Creyke, The Venerable Archdeacon. Bolton Percy Rectory, Tadcaster.
1880. *Crisp, Frank, B.A., LL.B. 5 Lansdowne-road, Notting Hill, London, W.
1858. ‡Crofts, John. Hillary-place, Leeds.
1878. §Croke, John O'Byrne, M.A. The French College, Blackrock; and 79 Strand-road, Sandymount, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879.§§Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 16 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1870. *Crosfield, William, jun. 16 Alexandra-drive, Prince's Park, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.

Year of Election.

1867. §CROSSKEY, Rev. H. W., F.G.S. 28 George-road, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. . Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1861. §Crowley, Henry. Trafalgar-road, Birkdale Park, Southport.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. ‡Crust, Walter. Hall-street, Spalding.
Culley, Robert. Bank of Ireland, Dublin.
1878. §Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Elms, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. The Elms, Handforth, Manchester.
1877. ‡Cunningham, D. J., M.D. University of Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1855. ‡Cunningham, William A. 2 Broadwalk, Buxton.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.G.S., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, Professor ARTHUR HILL, LL.D. Queen's College, Galway.
1878. §Curtis, William. Caramore, Sutton, Co. Dublin.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H., F.R.S. The Parsonage, Woolton, Liverpool.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡*Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.*
1859. ‡Dalrymple, Colonel. Troup, Scotland.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡DANBY, T. W. Downing College, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1876. ‡Darling, G. Erskine. 247 West George-street, Glasgow.
DARWIN, CHARLES R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E. and M.R.I.A. Down, near Bromley, Kent.
1878. §Darwin, Horace. Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.

Year of Election.

1878. ‡D'Aulmay, G. 22 Upper Leeson-street, Dublin.
1872. ‡Davenport, John T. 64 Marine Parade, Brighton.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1871. ‡Davidson, James. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, F.R.S., F.G.S. 3 Leopold-road, Brighton.
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1873. *Davis, Alfred. 5 Westminster Chambers, London, S.W.
1870. *Davis, A. S. 12 Suffolk-square, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1873. *Davis, James W., F.G.S., F.S.A. Chevinedge, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, near Compton, Bristol.
1859. ‡DAVIS, J. BARNARD, M.D., F.R.S., F.S.A. Shelton, Hanley, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1873. ‡Davis, William Samuel. 1 Cambridge Villas, Derby.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., jun. Llanferris, Mold, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A., Professor of Geology in Owens College, Manchester. Birchview, Norman-road, Rusholme, Manchester.
Dawson, John. Barley House, Exeter.
1855. ‡DAWSON, JOHN W., M.A., LL.D., F.R.S., F.G.S., Principal of M'Gill College, Montreal, Canada.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1879. §Day, Francis. Kenilworth House, Cheltenham.
1871. ‡DAY, ST. JOHN VINCENT, C.E., F.R.S.E. 166 Buchanan-street, Glasgow.
1870. §DEACON, G. F., M.I.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1859. ‡*Dean, David. Banchory, Aberdeen.*
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, B.A., D.Sc., F.G.S. Spring Hill College, Moseley, near Birmingham.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S., Lecturer on Chemistry at Guy's Hospital, London, S.E.
1878. §Delany, Rev. William. St. Stanislaus College, Tullamore.
1854. *DE LA RUE, WARREN, M.A., D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1879. §§De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1870. ‡De Meschin, Thomas, M.A., LL.D. 4 Hare-court, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
1875. ‡Denny, William. Seven Ship-yard, Dumbarton.

Year of Election.

Dent, William Yerbury. Royal Arsenal, Woolwich.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1874. §De Rance, Charles E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *Derby, The Right Hon. the Earl of, M.A., LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, M.A., LL.M., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.
*Devonshire, His Grace the Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James, M.A., F.R.S., F.R.S.E., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural Experimental Philosophy in the University of Cambridge. Brookside, Cambridge.
1872. ‡Dewick, Rev. E. S. 2 Southwick-place, Hyde Park, London, W.
1873. *Dew-Smith, A. G. 7a Eaton-square, London, S.W.
1852. ‡Dickie, George, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1867. ‡Dickson, Alexander, M.D., Professor of Botany in the University of Glasgow. 11 Royal-circus, Edinburgh.
1862. *Dilke, Sir Charles Wentworth, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. §Dillon, James, C.E. 2 Belgrave-road, Monkstown, Co. Dublin.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwerne, near Swansea.
1872. §Dines, George. Woodside, Hersham, Walton-on-Thames.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1876. ‡Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.
1868. ‡Dittmar, W. Andersonian University, Glasgow.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1853. ‡Dixon, Edward, M.I.C.E. Wilton House, Southampton.
1879. *Dixon, Harold B., M.A., F.C.S. Trinity College, Oxford.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne Park, London, W.
1878. *Dobson, G. E., M.A., M.B., F.L.S. Royal Victoria Hospital, Netley, Southampton.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.
1870. *Dodd, John. 6 Thomas-street, Liverpool.
1876. ‡Dodds, J. M. 15 Sandyford-place, Glasgow.

Year of Election.

*Dodsworth, Benjamin. Burton House, Scarborough.
*Dodsworth, George. The Mount, York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1873. ‡Donham, Thomas. Huddersfield.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1874. ‡Donnell, Professor, M.A. 76 Stephen's-green South, Dublin.
1861. ‡Donnelly, Colonel, R.E. South Kensington Museum, London, W.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, Charles Montagu. Theberton Hall, Saxmundham, Suffolk.
1876. *Douglas, Rev. G. C. M. 10 Fitzroy-place, Glasgow.
1877. *Douglass, James N., C.E. Trinity House, London, E.C.
1878. ‡Douglass, William. 104 Baggot-street, Dublin.
1855. ‡*Dove, Hector. Rose Cottage, Trinity, near Edinburgh.*
1870. ‡Dowie, J. Muir. Wetstones, West Kirby, Cheshire.
1876. §Dowie, Mrs. Muir. Wetstones, West Kirby, Cheshire.
1878. ‡Dowling, Thomas. Claireville House, Terenure, Dublin.
1857. ‡Downing, S., C.E., LL.D., Professor of Civil Engineering in the University of Dublin. 4 The Hill, Monkstown, Co. Dublin.
1878. ‡Dowse, The Right Hon. Baron. 38 Mountjoy-square, Dublin.
1872. *Dowson, Edward, M.D. 117 Park-street, London, W.
1865. *Dowson, E. Theodore. Geldeston, near Beccles, Suffolk.
1868. ‡Dresser, Henry E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873. §Drew, Frederic, F.G.S., F.R.G.S. Eton College, Windsor.
1869. §Drew, Joseph, LL.D., F.R.A.S., F.G.S. Weymouth.
1879. §§Drew, Joseph, M.B. Foxgrove-road, Beckenham, Kent.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1879. §§Drew, Samuel, M.D., D.Sc., F.R.S.E. Chapeltown, Edinburgh.
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
1874. ‡Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.
1856. *Ducie, The Right. Hon. Henry John Reynolds Moreton, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Holmfield House, Grassendale, Liverpool.
1867. *Duff, Mountstuart Elphinstone Grant-, LL.B., M.P. York House, Twickenham, Middlesex.
1852. ‡Dufferin and Clandeboye, The Right Hon. the Earl of, K.P., K.C.B., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange, C.E. Waterford.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. §§Duncan, Peter Martin, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 4 St. George's-terrace, Regent's Park-road, London, N.W.

Year of
Election.

1880. §Duncan, William S. 79 Wolverhampton-road, Stafford.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1876. *Dunn, James. 64 Robertson-street, Glasgow.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
*Earnshaw, Rev. Samuel, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *Easton, Edward, C.E., F.G.S. 7 Delahay-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John, C.E. Durie House. Abercromby-street, Helensburgh, N.B.
1870. §Eaton, Richard. Nuttall House, Nuttall, Nottinghamshire.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Martinstown, Dorchester.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
**Edgeworth, Michael P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.*
1855. ‡*Edmiston, Robert. Elmbank-crescent, Glasgow.*
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 72 Portsdown-road, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. ‡Edward, James. Balruddery, Dundee.
1855. *Edwards, Professor J. Baker, Ph.D., D.C.L. Montreal, Canada.
1867. ‡Edwards, William. 70 Princes-street, Dundee.
*Egerton, Sir Philip de Malpas Grey, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1873. ‡Elcock, Charles. 39 Lyme-street, Shakspere-street, Ardwick, Manchester.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1880. *Elliot, Colonel Charles, C.B. Wateringbury, Maidstone, Kent.
1855. §Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.
1861. *Elliot, Sir Walter, K.C.S.I., F.R.S., F.L.S. Wolfelee, Hawick, N.B.

Year of Election.

1864. ‡Elliott, E. B. Washington, United States.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
1879. §Elliott, Joseph W. Knowsley-street, Preston.
1864. *Ellis, Alexander John, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.
1877. ‡Ellis, Arthur Devonshire. School of Mines, Jermyn-street, London, S.W.; and Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. Fair Park House, Exeter.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1880. §Ellis, J. H. Town Hall, Southport.
1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. ‡Ellis, William Horton. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Stratton, Cornwall.
Enniskillen, The Right Hon. William Willoughby, Earl of, LL.D., D.C.L., F.R.S., F.G.S., M.R.I.A. 65 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, F.R.S., F.R.C.S., Professor of Clinical Surgery in University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.
1878. §§Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡Etheridge, Robert, F.R.S. L. & E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.
1870. *Evans, Arthur John, F.S.A. Nash Mills, Hemel Hempsted.
1865. *Evans, Rev. Charles, M.A. The Rectory, Solihull, Birmingham.
1876. ‡Evans, Captain Frederick J. O., C.B., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. 116 Victoria-street, Westminster, S.W.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledon, S.W.
1861. *Evans, John, D.C.L., LL.D., V.P.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempsted.
1876. ‡Evans, Mortimer, C.E. 97 West Regent-street, Glasgow.
1865. ‡Evans, Sebastian, M.A., LL.D. Highgate, near Birmingham.
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.
1871. §Eve, H. Weston, M.A. University College, London, W.C.

Year of Election.

1868. *EVERETT, J. D., M.A., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1880. §Everingham, Edward. St. Helen's-road, Swansea.
1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1874. ‡Ewart, William. Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1876. *Ewing, James Alfred, B.Sc., F.R.S.E., Professor of Mechanical Engineering in the University of Tokio, Japan. 12 Laurel Bank, Dundee.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warrens, near Lyndhurst, Hants.
1866. ‡EYRE, Major-General Sir VINCENT, K.C.S.I., F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1865. ‡Fairley, Thomas, F.R.S.E., F.C.S. 8 Newington-grove, Leeds.
1876. ‡Fairlie, James M. Charing Cross Corner, Glasgow.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1878. *Fairlie, Robert F. Palace-chambers, Victoria-street, Westminster, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1877. §Faraday, F. J., F.S.S. College Chambers, 17 Brazenose-street, Manchester.
1879. **Farnworth, Ernest. Swindon, near Dudley.*
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. §§FARR, WILLIAM, C.B., M.D., D.C.L., F.R.S. 78 Portsdown-road, Maida Hill, London, W.
1866. *FARRAR, Rev. FREDERICK WILLIAM, M.A., D.D., F.R.S., Canon of Westminster. St. Margaret's Rectory, Westminster, S.W.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. The Grange, Greenhill Park, New Barnet, Herts.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *FAWCETT, The Right Hon. HENRY, M.A., M.P., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 8 Trumpington-street, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1873. *Fazakerley, Miss. The Castle, Denbigh.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *FELLOWS, FRANK P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1876. *Fergus, Andrew, M.D. 3 Elmbank-crescent, Glasgow.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Sir Samuel, LL.D., Q.C. 20 Great George's-street North, Dublin.

Year of
Election.

1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *Fernie, John. Bonchurch, Isle of Wight.
1862. ‡Ferrers, Rev. Norman MacLeod, M.A., F.R.S. Caius College, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., F.R.S., Professor of Forensic Medicine in King's College. 16 Upper Berkeley-street, London, W.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *Field, Rogers, B.A., C.E. 5 Cannon-row, Westminster, S.W.
1876. ‡*Fielden, James. 2 Darnley-street, Pollokshields, near Glasgow.*
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1878. *Findlater, William. 2 Fitzwilliam-square, Dublin.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *Fischer, William L. F., M.A., LL.D., F.R.S. St. Andrews, Scotland.
1858. ‡Fishbourne, Admiral E. G., R.N. 26 Hogarth-road, Earl's Court-road, London, S.W.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlston Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. §§Fisher, William. Norton Grange, near Sheffield.
1875. *Fisher, W. W., M.A., F.C.S. 2 Park-crescent, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. ‡Fitch, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §Fitzgerald, George Francis. Trinity College, Dublin.
1857. ‡Fitzgerald, The Right Hon. Lord Otho. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §Fletcher, Alfred E. 5 Edge-lane, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1869. ‡Fletcher, Lavington E., C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡Flower, William Henry, LL.D., F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1877. *Floyer, Ernest A., F.R.G.S. 7 The Terrace, Putney, S.W.
1879. §§Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1879. §§Foote, Harry D'Oyley, M.D. Rotherham, Yorkshire.
1880. §Foote, R. Bruce. Linkwood, Central Hill, Upper Norwood, London, S.E.

Year of
Election.

1873. *Forbes, Professor George, M.A., F.R.S.E. Andersonian University, Glasgow.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1877. §Forbes, W. A. West Wickham, Kent.
Ford, H. R. Morecombe Lodge, Yealand Conyers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *FORDHAM, H. GEORGE, F.G.S. Odsey Grange, Royston, Herts.
*Forrest, William Hutton. 1 Pitt-terrace, Stirling.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1858. *FORSTER, The Right Hon. WILLIAM EDWARD, M.P., F.R.S. 80 Eccleston-square, London, S.W.; and Wharfeside, Burley-in-Wharfedale, Leeds.
1854. *Fort, Richard. Read Hall, Whalley, Lancashire.
1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1870. ‡Forwood, William B. Hopeton House, Seaforth, Liverpool
1875. ‡Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.G.S. Llandudno.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.
*Foster, Rev. John, M.A. The Oaks Vicarage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., F.R.S., F.L.S., F.C.S. Trinity College, and Great Shelford, near Cambridge.
1873. ‡*Foster, Peter Le Neve.*
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Brundall Lodge, Ealing, Middlesex, W.
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.
1870. ‡*Foulger, Edward. 55 Kirkdale-road, Liverpool.*
1866. ‡Fowler, George, M.I.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1876. *Fowler, John. 4 Kelvin Bank-terrace, Glasgow.
1870. *Fowler, Robert Nicholas, M.A., F.R.G.S. 50 Cornhill, London, E.C.
*Fox, Rev. Edward, M.A. Upper Heyford, Banbury.
1876. ‡Fox, G. S. Lane. 9 Sussex-place, London, S.W.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
1866. *Francis, G. B. Inglesby House, Stoke Newington-green, London, N.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster-gate, London, W.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S. L. & E. 3 Grosvenor-street, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.

Year of Election.

1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1877. §Freeman, Francis Ford. Blackfriars House, Plymouth.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1880. §Freeman, Thomas. Brynhyfryd, Swansea.
Frere, George Edward, F.R.S. Roydon Hall, Diss, Norfolk.
1869. ‡FRERE, The Right Hon. Sir H. BARTLE E., Bart., G.C.S.I., G.C.B., F.R.S., F.R.G.S. 34 Hyde Park-gardens, London, W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
1857. *Frith, Richard Hastings, C.E., M.R.I.A., F.R.G.S.I. 48 Summerhill, Dublin.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse Hill, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
1872. *Fuller, Rev. A. Pallant, Chichester.
1873. ‡*Fuller, Claude S., R.N.* 44 *Holland-road, Kensington, London, W.*
1859. ‡FULLER, FREDERICK, M.A., Professor of Mathematics in the University and King's College, Aberdeen.
1869. ‡FULLER, GEORGE, C.E., Professor of Engineering in Queen's College, Belfast. 6 College-gardens, Belfast.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Richmond Hill, Sheffield.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, Professor W. T., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
GALBRAITH, Rev. J. A., M.A., M.R.I.A. Trinity College, Dublin.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. ‡GALLOWAY, W., H.M. Inspector of Mines. Cardiff.
1860. *GALTON, Captain DOUGLAS, C.B., D.C.L., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, Lieut.-Colonel D. St. Helen's, Lancashire.
1870. ‡Gamble, J. C. St. Helen's, Lancashire.
1872. *Gamble, John G., M.A. Civil Service Club, Capetown. (Care of Messrs. Ollivier and Brown, 37 Sackville-street, Piccadilly, London. W.)
1877. ‡Gamble, William. St. Helen's, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., F.R.S.E., Professor of Physiology in Owens College, Manchester. Fairview, Princes-road, Fallowfield, Manchester.
1862. §§GARNER, ROBERT, F.L.S. Stoke-upon-Trent.

Year of Election.

1865.§§Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1873. ‡Garnham, John. 123 Bunhill-row, London, E.C.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1875. §Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S. Newton Abbott, Devon.
1873. ‡*Geach, R. G. Cragg Wood, Rawdon, Yorkshire.*
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M A., Professor of Greek in King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. ‡Geikie, Archibald, LL.D., F.R.S. L. & E., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Boroughfield, Edinburgh.
1871. §Geikie, James, F.R.S. L. & E., F.G.S. Balbraith, Perth.
1855. ‡*Gemmell, Andrew. 38 Queen-street, Glasgow.*
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1854. ‡*Gerard, Henry. 8a Rumford-place, Liverpool.*
1870. ‡Gerstl, R., F.C.S. University College, London, W.C.
1870. *Gervis, Walter S., M.D., F.R.S. Ashburton, Devonshire.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡*Gibson, Alexander. 10 Albany-street, Edinburgh.*
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1876. *Gibson, George Alexander, M.B., D.Sc., F.G.S. 1 Randolph Cliff, Edinburgh.
*Gibson, George Stacey. Saffron Walden, Essex.
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 10 Parkfield-road, Prince's Park, Liverpool.
1842. Gilbert, Joseph Henry, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1878. §Giles, Oliver. 16 Bellevue-crescent, Clifton, Bristol.
Giles, Rev. William. Netherleigh House, near Chester.
1878. ‡Gill, Rev. A. W. H. 44 Eaton-square, London, S.W.
1871. *Gill, David. The Observatory, Cape Town.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡Gill, Thomas. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley Hall, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1876. §Gimingham, Charles H. 45 St. Augustine's-road, Camden-square, London, N.W.
1867.§§Ginsburg, Rev. C. D., D.C.L., LL.D. Wokingham, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.

Year of Election.

1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1875. *Glaisher, Ernest Henry. 1 Dartmouth-place, Blackheath, London, S.E.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1870. §Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
1874. ‡Glover, Thomas. 77 Claverton-street, London, S.W.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. §Godman, F. D. 10 Chandos-street, Cavendish-square, London, W.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §Godwin-Austen, Major H. H., F.R.S., F.Z.S. 17 Bessborough-gardens, London, S.W.
1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1877. ‡GOFF, JAMES. 11 Northumberland-road, Dublin.
1873. ‡Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1878. ‡Good, Rev. Thomas, B.D. 51 Wellington-road, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. ‡*Goodison, George William, C.E. Gateacre, Liverpool.*
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1878. §GORDON, J. E. H., B.A. (ASSISTANT SECRETARY.) Holmwood Cottage, Dorking.
1871. *Gordon, Joseph Gordon, F.C.S. 20 King-street, St. James's, London, S.W.
1840. ‡*Gordon, Lewis D. B. Totteridge, Whetstone, London, N.*
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, LL.D., F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. ‡Gossage, William. Winwood, Woolton, Liverpool.
1875. *Gotch, Francis. Stokes Croft, Bristol.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §§Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. St. Helen's, Booterstown, Dublin.
1868. ‡Gould, Rev. George. Unthank-road, Norwich.
GOULD, JOHN, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.

Year of Election.

1876. §Gow, Robert. Cairndowan, Dowanhill, Glasgow.
Gowland, James. London-wall, London, E.C.
1873.§§Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W.. Park-road, Whalley Range, Manchester.
1867. *GRAHAM, CYRIL, F.L.S., F.R.G.S. Colonial Office, London, S.W.
1875. ‡GRAHAME, JAMES. Auldhouse, Pollokshaws, near Glasgow.
1852. *Grainger, Rev. Canon John, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.
1871. ‡GRANT, Sir ALEXANDER, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1859. ‡*Grant, Hon. James. Cluny Cottage, Forres.*
1870. ‡GRANT, Colonel James A., C.B., C.S.I., F.R.S., F.L.S., F.R.G.S. 19 Upper Grosvenor-street, London, W.
1855. *GRANT, ROBERT, M.A., LL.D.. F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡GRANTHAM, RICHARD B., C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1874. ‡Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stonyford, Co. Kilkenny.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1864. ‡Gray, Jonathan. Summerhill House, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. ‡Gray, J. Macfarlane. 127 Queen's-road, Peckham, London, S.E.
1878. §Gray, Matthew Hamilton. 14 St. John's Park, Blackheath, London, S.E.
1878. §Gray, Robert Kaye. 14 St. John's Park, Blackheath, London, S.E.
1873.§§Gray, William, M.R.I.A. 6 Mount Charles, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1854. *Grazebrook, Henry. Clent Grove, near Stourbridge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 101 Friar-gate, Derby.
1873. ‡*Greaves, James H., C.E. Albert-buildings, Queen Victoria-street, London, E.C.*
1869.§§Greaves, William. Station-street, Nottingham.
1872.§§Greaves, William. 3 South-square, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1879.§§Green, A. F. Leeds.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. ‡Greenwood, Frederick. School of Medicine, Leeds.
1862. *Greenwood, Henry. 32 Castle-street, and the Woodlands, Anfield-road, Anfield, Liverpool.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡GREGOR, Rev. WALTER, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.

Year of Election.

1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1875. ‡Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
*GRESWELL, Rev. RICHARD, M.A., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
1869. ‡GREY, Sir GEORGE, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1875. ‡Grey, Mrs. Maria G. 18 Cadogan-place, London, S.W.
1871. *Grierson, Samuel, Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1875. §Grieve, David, F.R.S.E., F.G.S. Hobart House, Dalkeith, Edinburgh.
1870. ‡*Grieve, John, M.D. 21 Lynedock-street, Glasgow.*
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *GRIFFITH, GEORGE, M.A., F.C.S. Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1870. ‡Griffith, Rev. Henry, F.G.S. Barnet, Herts.
1868. ‡*Griffith, Rev. John, M.A., D.C.L. Findon Rectory, Worthing, Sussex.*
1870. ‡Griffith, N. R. The Coppa, Mold, North Wales.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
GRIFFITHS, Rev. JOHN, M.A. Wadham College, Oxford.
1879. §§Griffiths, Thomas, F.C.S., F.S.S. Silverdale, Oxton, Birkenhead.
1875. ‡Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY, F.G.S. 18 Elgin-road, St. Peter's Park, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. 20 Cork-street, Burlington-gardens, London, W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., D.C.L., F.R.S. 115 Harley-street, London, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, HOWARD, F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *GUISE, Lieut.-Colonel Sir WILLIAM VERNON, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1877. ‡Gunn, William, F.G.S. Barnard Castle, Darlington.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, London, W.C.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *GURNEY, SAMUEL, F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Holgate Lodge, York.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1859. ‡GUTHRIE, FREDERICK, B.A., F.R.S. L. & E., Professor of Physics in the Royal School of Mines. Science Schools, South Kensington, London, S.W.
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡Gwyther, R. F. Owens College, Manchester.

Year of Election.

1865. ‡Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.
1866. *Hadden, Frederick J. South Cliff, Scarborough.
1866. ‡*Haddon, Henry. Lenton Field, Nottingham.*
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1879. §Hake, H. Wilson, Ph.D., F.C.S. Queenswood College, Hants.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington. London, W.
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
1872. *Hall, Captain Marshall. 13 Old-square, Lincoln's Inn, London, W.C.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. ‡Hall, Walter. 11 Pier-road, Erith.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1868. *HALLETT, WILLIAM HENRY, F.L.S. Buckingham House, Marine Parade, Brighton.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. The Leys, Barrow-on-Soar, near Loughborough.
1866. §§HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1869. §Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1878. ‡Hanagan, Anthony. Luckington, Dalkey.
1878. §Hance, Edward M., LL.B. 103 Hartington-road, Sefton Park, Liverpool.
1875. ‡Hancock, C. F., jun., M.A. 36 Blandford-square, London, N.W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London, N.
1857. ‡Hancock, William J. 23 Synnot-place, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D., M.R.I.A. 64 Upper Gardiner-street, Dublin.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry
Handyside, P. D., M.D., F.R.S.E. Edinburgh.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. Cowley Grange, Oxford.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.

Year of Election.
1869. ‡Harding, Joseph. Millbrooke House, Exeter.
1877. §Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1874. ‡Hardman, E. T., F.C.S. 14 Hume-street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
1880. §Hardy, John. 118 Embden-street, Manchester.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1876. ‡Harker, Allen. 17 Southgate-street, Gloucester.
1878. *Harkness, H. W. Sacramento, California.
1871. §§Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. Brompton, Wykeham Station, York.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and Burton Bank, Mill Hill, Middlesex, N.W.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1872. §§Harpley, Rev. William, M.A., F.C.P.S. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Oxton Hall, Tadcaster.
*Harris, Alfred, jun. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1863. ‡Harris, T. W. Grange, Middlesbrough-on-Tees.
1873. ‡*Harris, W. W. Oak-villas, Bradford, Yorkshire.*
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1873. ‡Harrison, George, Ph.D., F.L.S., F.C.S. 14 St. James's-row, Sheffield.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. Junior Oxford and Cambridge Club, St. James's-square, London, S.W.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1849. ‡HARROWBY, The Right Hon. DUDLEY RYDER, Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1876. *Hart, Thomas. Bank View, 33 Preston New-road, Blackburn.
1875. §§Hart, W. E. Kilderry, near Londonderry.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1854. §§HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea, Douglas-road, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1878. ‡Harvey, R. J., M.D. 7 Upper Merrion-street, Dublin.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.

Year of Election.

1875. ‡HASTINGS, G. W., M.P. Barnard's Green House, Malvern.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1837. ‡*Hastings, W. Huddersfield.*
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1874. ‡Hawkins, B. Waterhouse, F.G.S. Century Club, East Fifteenth-street, New York.
1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, S.W.
*HAWKSHAW, Sir JOHN, C.E., F.R.S., F.G.S., F.R.G.S. Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., F.G.S. 25 Cornwall-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. ‡HAWKSLEY, THOMAS, C.E., F.R.S., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *HAY, Rear-Admiral the Right Hon. Sir JOHN C. D., Bart., C.B., M.P., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1873. *Hayes, Rev. William A., M.A. 3 Mountjoy-place, Dublin.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. The Park, Harrow.
1879. *Hazlehurst, George S. The Elms, Runcorn.
1851. §HEAD, JEREMIAH, C.E., F.C.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1865. ‡Hearder, William. Rocombe, Torquay.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §§HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham
1858. *HEATON, JOHN DEAKIN, M.D., F.R.C.P. Claremont, Leeds.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1855. ‡HECTOR, JAMES, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡HEDDLE, M. FOSTER, M.D., Professor of Chemistry in the University of St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London, W.
1873. *Henderson, A. L. 49 King William-street, London, E.C.

Year of Election.

1874. ‡Henderson, James Alexander. Norwood Tower, Belfast.
1876. *Henderson, William. Williamfield, Irvine, N.B.
1873. *Henderson, W. D. 9 University-square, Belfast.
1856. ‡Hennessy, Henry G., F.R.S., M.R.I.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science for Ireland. 3 Idrone-terrace, Blackrock, Co. Dublin.
1857. ‡Hennessy, John Pope, C.M.G, Governor and Commander-in-Chief of Hong Kong.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Applied Mathematics in University College, London. Meldorf Cottage, Greenhill Park, Harlesden, London, N.W.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.
1874. ‡Henry, Rev. P. Shuldam, D.D., M.R.I.A. Belfast.
*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S., F.C.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. 12 Medina-villas, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Baldwyns, Bexley, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. ‡*Hepburn, Thomas H. St. Mary's Cray, Kent.*
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
1866. ‡Herrick, Perry. Bean Manor Park, Loughborough.
1871. *Herschel, Professor Alexander S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.
1874. §§Herschel, Major John, R.E., F.R.S. Mussoorie, N. W. P. India. (Care of Messrs. H. Robertson & Co., 5 Crosby-square, London, E.C.)
1865. ‡Heslop, Dr. Birmingham.
1873. ‡*Heugh, John. Gaunt's House, Wimborne, Dorset.*
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1879. §Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1861. *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1875. ‡Hicks, Henry, M.D., F.G.S. Heriot House, Hendon, Middlesex, N.W.
1877. §Hicks, W. M. St. John's College, Cambridge.
1864. *Hiern, W. P., M.A. Castle House, Barnstaple.
1854. *Higgin, Edward. Troston Lodge, near Bury St. Edmunds.
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡Higgins, Clement, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1854. ‡Higgins, Rev. Henry H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Holmwood, Turvey, near Bedford.
1870. ‡Higginson, Alfred. 135 Tulse Hill, London, S.W.

Year of Election.

Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1880. §Hill, Benjamin. Cwmdwr, near Clydach, Swansea.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. §Hill, John, C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡Hill, Lawrence. The Knowe, Greenock.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡Hinde, G. J. Buenos Ayres.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. **Hinmers, William. Cleveland House, Birkdale, Southport.*
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S. 29 Erskine-street, Liverpool.
*Hoare, Rev. Canon. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1879. §Hobkirk, Charles P., F.L.S. Huddersfield.
1879. §Hobson, John. Tapton Elms, Sheffield.
1866. ‡Hockin, Charles, M.D. 8 Avenue-road, St. John's Wood, London, N.W.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1880. §Hodgkinson, W. R. Eaton, Ph.D. Science Schools, South Kensington Museum, London, S.W.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1830. ‡Hodgson, W. B., LL.D., F.R.A.S., Professor of Commercial and Political Economy in the University of Edinburgh.
1865. *Hofmann, August Wilhelm, M.D., LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1860. ‡Hogan, Rev. A. R., M.A. Watlington Vicarage, Oxfordshire.
1876. ‡*Hogg, Robert. 54 Jane-street, Glasgow.*
1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1879. §§Holland, Calvert Bernard. Ashdell, Broomhill, Sheffield.
1878. *Holland, Rev. F. W., M.A. Evesham.

Year of
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*Holland, Philip H. Home Office, London, S.W.
1865. ‡Holliday, William. New-street, Birmingham.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1876. ‡Holms, Colonel William, M.P. 95 Cromwell-road, South Kensington, London, S.W.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡Hooker, Sir Joseph Dalton, K.C.S.I., K.C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, Surrey.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Samuel F., B.A. Tamworth House, Mitcham Common, Surrey.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. ‡*Hope, William, V.C. Parsloes, Barking, Essex.*
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, John, F.R.S. 78 Holland-road, Kensington, London, W.
1871. *Hopkinson, John, F.L.S., F.G.S. 235 Regent-street, London, W.; and Wansford House, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J. Surrey House, Forest Hill, London, S.E.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
Houghton, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. Travellers' Club, London, S.W.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1879. *Howard, D. South Frith Lodge, Tonbridge.
1859. ‡*Howard, Captain John Henry, R.N. The Deanery, Lichfield.*
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1879. §§Hudson, Robert S., M.D. Redruth, Cornwall.
1867. ‡Hudson, William H. H., M.A. 19 Bennet's-hill, Doctors' Commons, London, E.C.; and St. John's College, Cambridge.
1858. *Huggins, William, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse Hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.

Year of Election.

1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1867. §HULL, EDWARD, M.A., F.R.S., F.G.S., Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡HUME, Rev. Canon ABRAHAM, D.C.L., LL.D., F.S.A. All Souls' Vicarage, Rupert-lane, Liverpool.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. §Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡HUNT, ROBERT, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburgh-street, London, W.C.
1879. §Huntington, A. K., Professor of Metallurgy in King's College, London. Abbeville House, Arkwright-road, Hampstead, London, N.W.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1875. ‡Hurnard, James. Lexden, Colchester, Essex.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. May Bank, Bournemouth.
1876. ‡Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.
1876. ‡*Hutchison, Peter.* 28 *Berkeley-terrace, Glasgow.*
1868. *Hutchison, Robert, F.R.S.E. 29 Chester-street, Edinburgh.
Hutton, Crompton. Putney Park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley, near Leeds.)
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1879. §Ibbotson, H. J. 26 Collegiate-crescent, Sheffield.
Ihne, William, Ph.D. Heidelberg.
1873. §§Ikin, J. I. 19 Park-place, Leeds.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.

Year of Election.

1858. ‡Ingham, Henry. Wortley, near Leeds.
1876. ‡Inglis, Anthony. Broomhill, Partick, Glasgow.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek in the University of Dublin. 2 Wellington-road, Dublin.
1870. *Inman, William. Upton Manor, Liverpool.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
1862. ‡ISELIN, J. F., M.A., F.G.S. South Kensington Museum, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1876. ‡Jack, William. 19 Lansdowne-road, Notting Hill, London, W.
1879. §Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road, Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, London, S.W.
1852. ‡JACOBS, BETHEL. 40 George-street, Hull.
1874. *Jaffe, John. Cambridge Villa, Strandtown, near Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney Hill, London, E.C.
1860. ‡James, Edward H. Woodside, Plymouth.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. Woodside, Plymouth.
1876. ‡Jamieson, J. L. K. The Mansion House, Govan, Glasgow.
1876. ‡Jamieson, Rev. Dr. R. 156 Randolph-terrace, Glasgow.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §§Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, London, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡*Jecks, Charles. 26 Langham-place, Northampton.*
1856. ‡Jeffery, Henry M., M.A., F.R.S. 438 High-street, Cheltenham.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, London, E.C.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., B.D., M.R.I.A. 64 Lower Leeson-street, Dublin.
1862. §§JENKIN, H. C. FLEEMING, F.R.S., M.I.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1873. §§Jenkins, Major-General J. J. 14 St. James's-square, London, S.W.

Year of
Election.

1880. *JENKINS, JOHN JONES. The Grange, Swansea.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, Woking Station, Surrey.
1872. ‡Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *JEVONS, W. STANLEY, M.A., LL.D., F.R.S., Professor of Political Economy in University College, London. 2 The Chestnuts, Branch Hill, Hampstead Heath, London, N.W.
1872. *Joad, George C. Oakfield, Wimbledon, Surrey, S.W.
1871. *Johnson, David, F.C.S., F.G.S. Irvon Villa, Grosvenor-road, Wrexham.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. §Johnson, James Henry, F.G.S., F.S.A. 73 Albert-road, Southport.
1866. ‡Johnson, John. Knighton Fields, Leicester.
1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870.§§Johnson, Richard C., F.R.A.S. Higher Bebington Hall, Birkenhead.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
*Johnson, Thomas. Bache Hurst, Liverpool-road, Chester.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
*Johnstone, James. Alva House, Alva, by Stirling, N.B.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1876. ‡Johnstone, William. 5 Woodside-terrace, Glasgow.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871.§§Jolly, William (H.M. Inspector of Schools). Inverness, N.B.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1877.§§Jones, Henry C., F.C.S. 166 Blackstock-road, London, N.
*Jones, Robert. 2 Castle-street, Liverpool.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. §Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S., Professor of Geology at the Staff College, Sandhurst. Powis Villa, Camberley, Surrey.
1847. ‡JONES, THOMAS RYMER, F.R.S. 52 Cornwall-road, Westbourne Park, London, W.
1864.§§JONES, Sir WILLOUGHBY, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
1875. *Jose, J. E. 3 Queen-square, Bristol.
*Joule, Benjamin St. John B., J.P. 28 Leicester-street, Southport, Lancashire.
1842. *JOULE, JAMES PRESCOTT, LL.D., F.R.S., F.C.S. 12 Wardle-road, Sale, near Manchester.
1847. ‡JOWETT, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John. Leeds.
1879.§§Jowitt, A. Hawthorn Lodge, Clarkehouse-road, Sheffield.

Year of Election.

1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.
1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.
Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.
*Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.R.S., F.G.S. 4 Auriol-road, West Kensington, London, W.

1868. *Kaines, Joseph, M.A., D.Sc. 401 Finsbury-pavement, London, E.C.
KANE, Sir ROBERT, M.D., LL.D., F.R.S., M.R.I.A., F.C.S., Principal of the Royal College of Cork. Fortland, Killiney, Co. Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
Kay, John Cunliff. Fairfield Hall, near Skipton.
Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.
1872. ‡Keames, William M. 5 Lower Rock-gardens, Brighton.
1875. ‡Keeling, George William. Tuthill, Lydney.
1878. *Kelland, William Henry. 110 Jermyn-street, London, S.W.; and Grettans, Bow, North Devon.
1876. ‡Kelly, Andrew G. The Manse, Alloa, N.B.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1875. ‡KENNEDY, ALEXANDER B. W., C.E., Professor of Engineering in University College, London. 9 Bartholomew-road, London, N.W.
1876. ‡Kennedy, Hugh. Redclyffe, Partickhill, Glasgow.
1865. ‡*Kenrick, William. Norfolk-road, Edgbaston, Birmingham.*
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Dougalston, Milngavie, N.B.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1876. ‡Kidston, J. B. West Regent-street, Glasgow.
1876. ‡Kidston, William. Ferniegair, Helensburgh, N.B.
1865. *Kinahan, Edward Hudson, M.R.I.A. 11 Merrion-square North, Dublin.
1878. ‡Kinahan, Edward Hudson, jun. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1875. *Kinch, Edward, F.C.S. Agricultural College, Home Department, Tokio, Japan. (Care of C. J. Kinch, Esq., 8 West Kensington-terrace, London, W.)
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne Park, London, W.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §KING, KELBURNE, M.D. 27 George-street, and Royal Institution, Hull.

Year of Election.

1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton, Bristol.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1876. §Kingston, Thomas. Strawberry House, Chiswick, Middlesex.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §KINGZETT, CHARLES T., F.C.S. 12 Auriol-road, The Cedars, West Kensington, London, W.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *KINNAIRD, The Right Hon. Lord. 2 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1863. ‡*Kirkaldy, David. 28 Bartholomew-road North, London, N.W.*
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1876. *Kirkwood, Anderson, LL.D., F.R.S.E. 12 Windsor-terrace West, Hillhead, Glasgow.
1875. ‡Kirsop, John. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. ‡Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
1836. Knipe, J. A. Botcherby, Carlisle.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1842. Knowles, John. The Lawn, Rugby.
1870. ‡Knowles, Rev. J. L. 103 Earl's Court-road, Kensington, London, W.
1874. §§Knowles, William James. Cullybackey, Belfast, Ireland.
1876. ‡Knox, David N., M.A., M.B. 8 Belgrave-terrace, Hillhead, Glasgow.
*Knox, George James. 2 Coleshill-street, Eaton-square, London, S.W.
1835. Knox, Thomas Perry. Union Club, Trafalgar-square, London, W.C.
1875. *Knubley, Rev. E. P. Staveley Rectory, Leeds.
1870. ‡Kynaston, Josiah W., F.C.S. St. Helen's, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1870. ‡Laird, H. H. Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1880. *Lake, Samuel. Milford Docks, Milford Haven.
1877. §Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 8 The Circus, Greenwich, London, S.E.
1859. ‡*Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.*
1864. ‡Lang, Robert. Langford Lodge, College-road, Clifton, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.

Year of Election.

*Langton, William. Docklands, Ingatestone, Essex.
1865. ‡LANKESTER, E. RAY, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. Exeter College, Oxford; and 11 Wellington Mansions, North Bank, London, N.W.
1880. *Lansdell, Rev. Henry. Eyre Cottage, Blackheath, London, S.E.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1861. *Latham, Arthur G. Lower King-street, Manchester.
1870. *LATHAM, BALDWIN, C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Greenwich, S.E.
1875. ‡Lavington, William F. 107 Pembroke-road, Clifton, Bristol.
1870. *Law, Channell. Sydney Villa, 36 Outram-road, Addiscombe, Croydon.
1878. ‡Law, Henry, C.E. 5 Queen Anne's-gate, London, S.W.
1857. ‡Law, Hugh, Q.C. 9 Fitzwilliam-square, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1876. ‡*Lawson, John. Cluny Hill, Forres, N.B.*
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Colonel R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1844. *Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton-green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1872. ‡LEBOUR, G. A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne. Weedpark House, Dipton, Lintz Green, Co. Durham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡*Lees, William. Link Vale Lodge, Viewforth, Edinburgh.*
*Leese, Joseph. Glenfield, Altrincham, Manchester.
1872. ‡LEFEVRE, G. SHAW, M.P., F.R.G.S. 18 Bryanston-square, London, W.
*LEFROY, Lieut.-General Sir JOHN HENRY, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S. Tasmania.
*Legh, Lieut.-Colonel George Cornwall, M.P. High Legh Hall, Cheshire; and 43 Curzon-street, Mayfair, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.

Year of Election.

1868. ‡LEICESTER, The Right Hon. the Earl of. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1880. §Leighton, William Henry, F.G.S. 2 Merton-place, Chiswick, S.W.
1867.§§Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1863. *LENDY, Major AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, Sir John, C.B., M.D. Tallaght House, Co. Dublin; and 1 Great Denmark-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §LEONARD, HUGH, F.G.S., M.R.I.A., F.R.G.S.I. Geological Survey of Ireland, 14 Hume-street, Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. ‡Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡LESLIE, T. E. CLIFFE, LL.B., Professor of Jurisprudence and Political Economy in Queen's College, Belfast.
1880. §LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1876. ‡*Leveson, Edward John. Cluny, Sydenham Hill, S.E.*
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1879.§§Lewin, Lieut.-Colonel. Tanhurst, Dorking.
1870. ‡LEWIS, ALFRED LIONEL. 151 Church-road, De Beauvoir Town, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, D.D., F.R.S., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
*Lindsay, Charles. Ridge Park, Lanark, N.B.
1871. *LINDSAY, The Right Hon. Lord, M.P., F.R.S. 47 Brook-street, London, W.
1870. ‡Lindsay, Thomas, F.C.S. 288 Renfrew-street, Glasgow.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
1876. §Linn, James. Geological Survey Office, India-buildings, Edinburgh.
Lister, James. Liverpool Union Bank, Liverpool.
1870. §Lister, Thomas. Victoria-crescent, Barnsley, Yorkshire.
1876. ‡Little, Thomas Evelyn. 42 Brunswick-street, Dublin.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.

Year of
Election.

1876. *Liversidge, Archibald, F.C.S., F.G.S., F.R.G.S., Professor of Geology and Mineralogy in the University of Sydney, N.S.W. (Care of Messrs. Trübner & Co., Ludgate Hill, London, E.C.)
1864. §§Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1880. §Llewelyn, John T. D. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
*Lloyd, George, M.D., F.G.S. Acock's-green, near Birmingham.
*LLOYD, Rev. HUMPHREY, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1877. *Lloyd, Sampson Samuel, M.P. Moor Hall, Sutton Coldfield.
1865. *Lloyd, Wilson, F.R.G.S. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington Park, London, W.
1853. *Locke, John. 133 Leinster-road, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 16 Penywern-road, South Kensington, London, S.W.
1875. *LODGE, OLIVER J., D.Sc. University College, London, W.C.; and 17 Parkhurst-road, London, N.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 727 Duke-street, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Osmaston-road, Derby.
LONGFIELD, The Right Hon. MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
1875. *Longstaff, George Blundell, M.A., M.B., F.C.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Lieut.-Colonel Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, S.W.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1876. *Love, James, F.R.A.S. 133 George-street, Paisley.
1875. *Lovett, W. J. 96 Lionel-street, Birmingham.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Shirenewton, near Chepstow.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853. *LUBBOCK, Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. (PRESIDENT ELECT.) High Elms, Farnborough, Kent.
1870. ‡Lubbock, Montague. High Elms, Farnborough, Kent.

Year of Election.

1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866. *Lund, Charles. 48 Market-street, Bradford, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. Teviot Bank, Newport Road, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *Lupton, Sydney, M.A. Harrow.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡*Lyell, Leonard. 42 Regent's Park-road, London, N.W.*
1874. ‡Lynam, James, C.E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., M.B., M.R.I.A. 8 Merrion-square West, Dublin.
1878. ‡Lyte, Cecil Maxwell. Cotford, Oakhill-road, Putney, S.W.
1862. *Lyte, F. Maxwell, F.C.S. Cotford, Oakhill-road, Putney, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. ‡M'Adam, William. 30 St. Vincent-crescent, Glasgow.
1876. *Macadam, William Ivison. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1878. §McAlister, Donald, B.A., B.Sc. St. Bartholomew's Hospital, London, E.C.
1879. §MacAndrew, James J. Lukesland, Ivybridge, Sheffield.
1866. *M'Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1838. Macaulay, Henry. 14 Clifton Bank, Rotherham, Yorkshire.
1840. Macaulay, James, A.M., M.D. 22 Cambridge-road, Kilburn, London, N.W.
1871. ‡*M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.*
*MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866. ‡M'Callan, Rev. J. F., M.A. Basford, near Nottingham.
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, Rev. James, D.D., F.G.S. 18 Shaftesbury-terrace, Glasgow.
1876. *M'Clelland, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1840. M'Clelland, James, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M'Clintock, Rear-Admiral Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *M'Clure, J. H. The Wilderness, Richmond, Surrey.
1874. ‡M'Clure, Sir Thomas, Bart. Belmont, Belfast.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1859. **M'Connell, David C., F.G.S. 44 Manor-place, Edinburgh.*
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1876. ‡M'Culloch, Richard. 109 Douglas-street, Blythswood-square, Glasgow.
1871. ‡M'Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)
1878. ‡McDonnell, Alexander. St. John's, Island Bridge, Dublin.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.

Year of Election.

1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1878. ‡McDonnell, Robert, M.D., F.R.S., M.R.I.A. 14 Lower Pembroke-street, Dublin.
*M'Ewan, John. 3 Douglas-terrace, Stirling, N.B.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1879. §§Macfarlane, Walter, jun. 22 Park-circus, Glasgow.
1854. *Macfie, Robert Andrew. Dreghorn, Colinton, Edinburgh.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡M'George, Mungo. Nithsdale, Laurie Park, Sydenham, S.E.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. 2 Laurence-place, Partick, Glasgow.
1876. ‡M'Grigor, Alexander B. 19 Woodside-terrace, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1874. ‡MacIlwaine, Rev. Canon, D.D., M.R.I.A. Ulsterville, Belfast.
1876. ‡Macindoe, Patrick. 9 Somerset-place, Glasgow.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'Intosh, W. C., M.D., F.R.S. L. & E., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Abercromby-square, Liverpool.
1871. ‡Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.
1873. ‡McKendrick, John G., M.D., F.R.S.E. 2 Chester-street, Edinburgh.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 24 Buckingham-place, Brighton.
1867. §Mackie, Samuel Joseph, C.E., F.G.S. 22 Eldon-road, Kensington, London, W.
*Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. Whitford-road, Tranmere, Birkenhead.
1850. ‡Macknight, Alexander. 12 London-street, Edinburgh.
1867. ‡Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLachlan, Robert, F.R.S., F.L.S. 39 Limes-grove, Lewisham, S.E.
1873. ‡McLandsborough, John, C.E., F.R.A.S., F.G.S. South Park Villa, Harrogate, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. ‡MacLaren, Duncan, M.P. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1876. ‡M'Lean, Charles. 6 Claremont-terrace, Glasgow.
1876. ‡M'Lean, Mrs. Charles. 6 Claremont-terrace, Glasgow.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden-hill-road, London, W.
1868. §M'Leod, Herbert, F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. ‡Macliver, D. 1 Broad-street, Bristol.
1875. ‡Macliver, P. S. 1 Broad-street, Bristol.
1861. *Maclure, John William. 2 Bond-street, Manchester.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey, S.W.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1871. ‡M'Nab, William Ramsay, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.
1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.

Year of Election.

1867. §M'Neill, John. Balhousie House, Perth.

MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.

1878. ‡Macnie, George. 59 Bolton-street, Dublin.

1852. *Macrory, Adam John. Duncairn, Belfast.

*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.

1876. *Mactear, James. 16 Burnbank-gardens, Glasgow.

1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.

1868. ‡Magnay, F. A. Drayton, near Norwich.

1875. *Magnus, Philip. 48 Gloucester-place, Portman-square, London, W.

1879. §§Mahomed, F. A. 13 St. Thomas-street, London, S.E.

1878. ‡Mahony, W. A. 34 College-green, Dublin.

1869. ‡Main, Robert. Admiralty, Whitehall, London, S.W.

1866. ‡Major, Richard Henry, F.S.A., Sec.R.G.S. British Museum, London, W.C.

*Malahide, The Right Hon. Lord Talbot de, M.A., D.C.L., F.R.S., F.G.S., F.S.A., M.R.I.A. Malahide Castle, Co. Dublin.

*Malcolm, Frederick. Morden College, Blackheath, London, S.E.

1870. **Malcolm, Sir James, Bart. 1 Cornwall-gardens, South Kensington, London, S.W.*

1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.

1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.

1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, U.S.

*Mallet, Robert, Ph.D., F.R.S., F.G.S., M.R.I.A. Enmore, The Grove, Clapham-road, Clapham, S.W.

1846. ‡Manby, Charles, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.

1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.

1866. §Mann, Robert James, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.

Manning, His Eminence Cardinal. Archbishop's House, Westminster, S.W.

1866. ‡Manning, John. Waverley-street, Nottingham.

1878. §§Manning, Robert. 4 Upper Ely-place, Dublin.

1864. ‡Mansel, J. C. Long Thorns, Blandford.

1870. ‡Marcoartu, Senor Don Arturo de. Madrid.

1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., Sec.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.

1863. ‡Marley, John. Mining Office, Darlington.

*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.

1871. ‡Marreco, A. Friere-. College of Physical Science, Newcastle-on-Tyne.

1857. ‡Marriott, William, F.C.S. Grafton-street, Huddersfield.

1842. Marsden, Richard. Norfolk-street, Manchester.

1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.

1865. ‡Marsh, J. F. Hardwick House, Chepstow.

1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.

1852. ‡Marshall, James D. Holywood, Belfast.

1876. ‡Marshall, Peter. 6 Parkgrove-terrace, Glasgow.

1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.

1849. *Marshall, William P. 14 Augustus-road, Birmingham.

1865. §Marten, Edward Bindon. Pedmore, near Stourbridge.

1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.

1878. ‡Martin, H. Newell. Christ's College, Cambridge.

Year of
Election.

1871. ‡Martin, Rev. Hugh, M.A. Greenhill Cottage, Lasswade, by Edinburgh.
1870. ‡*Martin, Robert, M.D. 120 Upper Brook-street, Manchester.*
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
*Martindale, Nicholas. Queen's Park, Chester.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. ‡Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1878. §§Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-stieet Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.P., M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. 112 Gloucester-terrace, Hyde Park-gardens, London, W.
1861. *Mason, Hugh. Groby Hall, Ashton-under-Lyne.
1879. §§Mason, James, M.D. Montgomery House, Sheffield.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
1876. §§Mason, Robert. 6 Albion-crescent, Dowanhill, Glasgow.
1876. ‡Mason, Stephen. 9 Rosslyn-terrace, Hillhead, Glasgow.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1876. ‡Matheson, John. Eastfield, Rutherglen, Glasgow.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 60 Harborne-road, Birmingham.
1876. *Mathiesen, John, jun. Cordale, Renton, Glasgow.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. ‡Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle on-Tyne.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1864. *Maxwell, Francis. St. Germains, Longniddry, East Lothian.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1868. ‡Mayall, J. E., F.C.S. Stork's Nest, Lancing, Sussex.
1835. Mayne, Edward Ellis. Rocklands, Stillorgan, Ireland.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1863. ‡Mease, George D. Bylton Villa, South Shields.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. H.M. Dockyard, Chatham.
1867. ‡MELDRUM, CHARLES, M.A., F.R.S., F.R.A.S. Port Louis, Mauritius.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General Count. 35 Queen's-gate, London, S.W.
1862. ‡MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.

Year of Election.

1879. §Merivale, John Herman. Nedderton R.S.O., Northumberland.
1879. §Merivale, Walter. Engineers' Office, North-Eastern Railway, Newcastle-on-Tyne.
1868. §MERRIFIELD, CHARLES W., F.R.S. 20 Girdler's-road, Brook Green, London, W.
1877. ‡Merrifield, John, Ph.D., F.R.A.S. Gascoigne-place, Plymouth.
1880. §Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1871. ‡*Merson, John. Northumberland County Asylum, Morpeth.*
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.G.S., Professor of Biology in Yorkshire College, Leeds.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1876. *Middleton, Robert T., M.P. 197 West George-street, Glasgow.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1863. ‡Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1876. ‡Millar, William. Highfield House, Dennistoun, Glasgow.
1876. ‡Millar, W. J. 145 Hill-street, Garnethill, Glasgow.
1876. ‡Miller, Daniel. 258 St. George's-road, Glasgow.
1875. ‡Miller, George. Brentry, near Bristol.
1861. *Miller, Robert. Poise House, Bosden, near Stockport.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1876. ‡Miller, Thomas Paterson. Morriston House, Cambuslang, N.B.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S. 6 Craven-street, Strand, London, W.C.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's College, Glasgow. 60 John-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
1880. §Mills, Mansfieldt H. Tapton-grove, Chesterfield.
Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. 13 New-street, Spring-gardens, London, S.W.
1867. ‡Milne, James. Murie House, Errol, by Dundee.
1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1864. *MILTON, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1880. §Minchin, G. M. Royal Indian Engineering College, Cooper's Hill, Surrey.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1870. ‡Mitchell, John. York House, Clitheroe, Lancashire.
1868. ‡Mitchell, John, jun. Pole Park House, Dundee.
1879. §§MIVART, ST. GEORGE, M.D., F.R.S., F.L.S., F.Z.S., Professor of Biology in University College, Kensington. 71 Seymour-street, London, W.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §§MOFFAT, THOMAS, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.

Year of Election.

1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. ‡MOGGRIDGE, MATTHEW, F.G.S. 8 Bina-gardens, South Kensington, London, S.W.
1855. ‡Moir, James. 174 Gallogate, Glasgow.
1861. ‡MOLESWORTH, Rev. W. NASSAU, M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1878. §Molloy, Constantine. 70 Lower Gardiner-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §MOLYNEUX, WILLIAM, F.G.S. Branston Cottage, Burton-upon-Trent.
1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1859. ‡MOORE, CHARLES, F.G.S. 6 Cambridge-place, Bath.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1877. ‡Moore, W. F. The Friary, Plymouth.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1877. ‡Moore, William Vanderkemp. 15 Princess-square, Plymouth.
1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1873. ‡Morgan, Edward Delmar. 15 Rowland-gardens, London, W.
1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.
1878. §MORGAN, WILLIAM, Ph.D., F.C.S. Swansea.
1867. ‡Morison, William R. Dundee.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
1880. §Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1880. §Morris, M. I. E. The Lodge, Penclawdd, near Swansea.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. §§Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1879. §§Morrison, Dr. R. Milner. 13 Douglas-crescent, Edinburgh.
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 122 London-road, Liverpool.
1858. *MORTON, HENRY JOSEPH. 4 Royal Crescent, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.

Year of Election.

Moss, John. Otterspool, near Liverpool.
1878. *Moss, JOHN FRANCIS. Ranmoor, Sheffield.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. 66 Kenilworth-square, Rathgar, Dublin.
1873. **Mosse, George Staley.* 16 *Stanford-road, London, W.*
1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.)
1873. ‡Mossman, William. Woodhall, Calverley, Leeds.
1869. §MOTT, ALBERT J., F.G.S. Adsett Court, Westbury-on-Severn.
1865. ‡Mott, Charles Grey. The Park, Birkenhead.
1866. §MOTT, FREDERICK T., F.R.G.S. Birstall Hill, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. F., F.R.S. 74 Onslow-gardens, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1876. *Muir, John. 6 Park-gardens, Glasgow.
1874. ‡Muir, M. M. Pattison, F.R.S.E. Owens College, Manchester.
1876. §Muir, Thomas. High School, Glasgow.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 29 Regency-street, Westminster, S.W.
1871. *MUIRHEAD, HENRY, M.D. Bushy Hill, Cambuslang, Lanarkshire.
1876. ‡Muirhead, R. F., B.Sc. Meikle Cloak, Lochwinnoch, Renfrewshire.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1880. §Muller, Hugo M. 1 Grunangergasse, Vienna.
1866. ‡MUNDELLA, The Right Hon. A. J., M.P., F.R.G.S. The Park, Nottingham.
1876. §Munro, Donald, F.C.S. 97 Eglinton-street, Glasgow.
1860. *MUNRO, Major-General WILLIAM, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.
1872. *Munster, H. Sillwood Lodge, Brighton.
1871. *Munster, William Felix. 41 Brompton-square, London, W.
1864. ‡MURCH, JEROM. Cranwells, Bath.
*Murchison, John Henry. Surbiton Hill, Kingston.
1864. *Murchison, K. R. Brokehurst, East Grinstead.
1876. ‡Murdoch, James. Altony Albany, Girvan, N.B.
1855. ‡Murdock, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. ‡Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. ‡Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. Downlands, Sutton, Surrey.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.

Year of Election.
1859. *Murton, James. Highfield, Silverdale, Carnforth.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1842. Nadin, Joseph. Manchester.
1876. §Napier, James S. 9 Woodside-place, Glasgow.
1876. ‡Napier, John. Saughfield House, Hillhead, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1839. *NAPIER, The Right Hon. Sir JOSEPH, Bart., D.C.L., LL.D. 4 Merrion-square South, Dublin.
1872. ‡Nares, Captain Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. 23 St. Philip's-road, Surbiton.
1866. ‡*Nash, Davyd W., F.S.A., F.L.S.* 10 *Imperial-square, Cheltenham.*
1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1864. ‡Natal, Rev. John William Colenso, D.D., Lord Bishop of. Natal.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡*Neilson, W. Montgomerie. Glasgow.*
1876. ‡Nelson, D. M. 48 Gordon-street, Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, C.E., M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡NEVILLE, PARKE, C.E., M.R.I.A. 58 Pembroke-road, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare Hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1879. §§Newbould, John. Sharrow Bank, Sheffield.
1866. *Newdigate, Albert L. 25 Craven-street, Charing Cross, London, W.C.
1876. §§Newhaus, Albert. 1 Prince's-terrace, Glasgow.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1863. *NEWMARCH, WILLIAM, F.R.S. Beech Holme, Balham, London, S.W.
1866. *Newmarch, William Thomas. 1 Elms-road, Clapham Common, London, S.W.
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Ashleigh, Ventnor, Isle of Wight.

Year of Election.

1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1871.§§Nicholson, E. Chambers. Herne Hill, London, S.E.
1867. ‡Nicholson, Henry Alleyne, M.D., D.Sc., F.G.S., Professor of Natural History in the University of St. Andrews, N.B.
1867. ‡Nimmo, Dr. Matthew. Nethergate, Dundee.
1878. ‡Niven, C. Queen's College, Cork.
1877. ‡Niven, James, M.A. King's College, Aberdeen.
‡Nixon, Randal C. J., M.A. Green Island, Belfast.
1863. *Noble, Captain Andrew, F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-on-Tyne.
1880. §Noble, John. Rossenstein, Thornhill-road, Croydon, Surrey.
1879.§§Noble, T. S., F.G.S. Lendal, York.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1860. *Nolloth, Rear-Admiral Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. Norgate, William. Newmarket-road, Norwich.
1863. §Norman, Rev. Alfred Merle, M.A. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡Norris Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Corphwysfa, Llanrwst, North Wales.
1869. ‡Northcote, The Right Hon. Sir Stafford H., Bart., K.G.C.B., M.P., F.R.S. Pynes, Exeter.
*Northwick, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1878. ‡Nugent, Edward, C.E. Seel's-buildings, Liverpool.

1878.§§O'Brien, Murrough. 1 Willow-terrace, Blackrock, Co. Dublin.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Carroll, Joseph F. 78 Rathgar-road, Dublin.
1878. ‡O'Connor Don, The, M.P. Clonalis, Castlerea, Ireland.
Odgers, Rev. William James. Savile House, Fitzjohn's-avenue, Hampstead, London, N.W.
1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. §Ogden, Joseph. 46 London-wall, London, E.C.
1876. ‡Ogilvie, Campbell P. Sizewell House, Lenton, Suffolk.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
1874. §Ogilvie, Thomas Robertson. Bank Top, 3 Lyle-street, Greenock, N.B.
*Ogilvie-Forbes, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. Boyndlie, Fraserburgh, N.B.
1863. ‡*Ogilvy, G. R. Inverquharity, N.B.*
1863. ‡Ogilvy, Sir John, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John, M.A., Q.C. 22 Upper Fitzwilliam-street, Dublin.

Year of Election.

1874. ‡O'HAGAN, The Right Hon. Lord, M.R.I.A. 34 Rutland-square West, Dublin.
1862. ‡O'KELLY, JOSEPH, M.A., M.R.I.A. 14 Hume-street, Dublin.
1853. §OLDHAM, JAMES, C.E. Cottingham, near Hull.
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, Surrey.
*OMMANNEY, Admiral Sir ERASMUS, C.B., F.R.S., F.R.A.S., F.R.G.S. The Towers, Yarmouth, Isle of Wight.
1880. *Ommanney, Commander E. A., R.N., 44 Charing Cross, London, W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1880. §O'Reilly, J. P., C.E., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1842. ORMEROD, GEORGE WAREING, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham Hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1880. *Ormiston, Thomas, C.E. Ormsdale, Thurlow Park-road, Dulwich, S.E.
1835. ORPEN, JOHN H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1876. ‡*Orr, John B. Granville-terrace, Crosshill, Glasgow.*
1873. ‡Osborn, George. 47 Kingscross-street, Halifax.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1877. *Osler, Miss A. F. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. 1 Pownall-gardens, Hounslow, near London.
1854. ‡Outram, Thomas. Greetland, near Halifax.
OVERSTONE, SAMUEL JONES LLOYD, Lord, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
OWEN, RICHARD, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1873. ‡Palmer, George. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1878. *Palmer, Joseph Edward. Lucan, Co. Dublin.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. Hawthorne, Rivercourt-road, Hammersmith, W.
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1880. §Parke, George Henry, F.L.S., F.G.S. Barrow-in-Furness, Lancashire.
1857. *Parker, Alexander, M.R.I.A. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Richard. Dunscombe, Cork.

Year of Election.

1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. 6 St. Mary's-row, Birmingham.
1864. ‡PARKES, WILLIAM. 23 Abingdon-street, Westminster, S.W.
1879. §Parkin, William, F.S.S. 15 Westbourne-road, Sheffield.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1841. Parnell, Edward A., F.C.S. Ashley Villa, Swansea.
1862. *Parnell, John, M.A. 1 The Common, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. 10 Connaught-place, London, W.
1878. ‡Parsons, Hon. and Rev. R. C. 10 Connaught-place, London, W.
1875. ‡Pass, Alfred C. 16 Redland Park, Clifton, Bristol.
1855. ‡*Paterson, William.* 100 *Brunswick-street, Glasgow.*
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. Henry. 3 Old-buildings, Lincoln's Inn, London, W.C.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1876. §§Patterson, T. L. Belmont, Margaret-street, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡Pattinson, John, F.C.S. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. §Pattison, Samuel Rowles, F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1877. ‡Payne, J. C. Charles. Botanic Avenue, Belfast.
1851. ‡*Payne, Joseph.* 4 *Kildare-gardens, Bayswater, London, W.*
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1876. ‡Peace, G. H. Morton Grange, Eccles, near Manchester.
1879. §§Peace, William K. Western Bank, Sheffield.
1847. ‡PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1876. ‡Pearce, W. Elmpark House, Govan, Glasgow.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.
1875. ‡*Pearson, H. W. Tramore Villa, Nugent Hill, Cotham, Bristol.*
1872. *Pearson, Joseph. Lern Side Works, Nottingham.
1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.

Year of Election.

1855. *Peckover, Alexander, F.L.S., F.R.G.S. Harecroft House, Wisbech, Cambridgeshire.
*Peckover, Algernon, F.L.S. Sibald's Holme, Wisbech, Cambridgeshire.
1878. *Peek, William. St. Clair, Hayward's Heath, Sussex.
*Peel, George. Soho Iron Works, Manchester.
1873. ‡Peel, Thomas. 9 Hampton-place, Bradford, Yorkshire.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.
1868. ‡Pendergast, Thomas. Lancefield, Cheltenham.
1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1875. ‡Percival, Rev. J., M.A., LL.D. President of Trinity College, Oxford.
1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., 1 Gloucester-crescent, Hyde Park, London, W.
*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.
1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow.
1877. §Perkins, Loftus. 140 Abbey-road, Kilburn, London, N.W.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. 54 Gloucester-street, London, S.W.
Perry, The Right Rev. Charles, M.A., D.D. 32 Avenue-road, Regent's Park, London, N.W.
1879. §§Perry, James. Roscommon.
1874. *Perry, John. 14 Talgarth-road, West Kensington, London, S.W.
*Perry, Rev. S. G. F., M.A. Tottington Vicarage, near Bury.
1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.M.S. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 1 Uplands, St. Leonard's-on-Sea.
1867. ‡PHAYRE, Lieut.-General Sir ARTHUR, K.C.S.I., C.B. Athenæum Club, Pall Mall, London, S.W.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
Philips, Robert N. The Park, Manchester.
1877. §Philips, T. Wishart. 33 Woodstock-road, Poplar, London, E.
1863. ‡Philipson, Dr. 1 Savile-row, Newcastle-on-Tyne.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1872. ‡PHILLIPS, J. ARTHUR. 18 Fopstone-road, Earl's Court-road, London, S.W.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D. 4 The Cedars, Putney, Surrey, S.W.
1864. ‡Pickering, William. Oak View, Clevedon.
1870. ‡Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. ‡*Pigot, Rev. E. V. Malpas, Cheshire.*
1871. ‡Pigot, Thomas F., C.E., M.R.I.A. Royal College of Science, Dublin.

Year of Election.

*Pike, Ebenezer. Besborough, Cork.
1865. ‡PIKE, L. OWEN. 25 Carlton-villas, Maida-vale, London, W.
1873. ‡Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., M.A., Q.C. 45 Upper Mount-street, Dublin.
1863. *PIM, Captain BEDFORD C. T., R.N., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
1877.§§Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡Pirie, Rev. G. Queen's College, Cambridge.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1868. *PITT-RIVERS, Major-General A. H. L., F.R.S., F.G.S., F.R.G.S., F.S.A. 19 Penywern-road, South Kensington, London, S.W.
1872. ‡Plant, Mrs. H. W. 28 Evington-street, Leicester.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp Hill, and 33 Union-street, Birmingham.
1842. PLAYFAIR, The Right Hon. LYON, C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel R. L., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S., M.I.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D., President of Queen's College, Belfast.
1866.§§Porter, Robert. Beeston, Nottingham.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, F.R.S. Camfield-place, Hatfield, Herts.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1875 ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1869. *PREECE, WILLIAM HENRY. Gothic Lodge, Wimbledon Common, London, S.W.
Prest, The Venerable Archdeacon Edward. The College, Durham.
*PRESTWICH, JOSEPH, M.A., F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 34 Broad-street, Oxford; and Shoreham, near Sevenoaks.

Year of Election.

1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford, 11 St. Giles's, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
Price, J. T. Neath Abbey, Glamorganshire.
1875. *Price, Rees. 2 Blythe-villas, West Kensington Park, London, W.
1870. *Price, Captain W. E., F.G.S. Tibberton Court, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1876. ‡Priestley, John. 174 Lloyd-street, Greenheys, Manchester.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1858. ‡Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. 25 Harrison-place, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. Westbourne House, Shaftesbury-road, London, W.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert. Tayside, Perth.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
Punnet, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College, Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1868. §§PYE-SMITH, P. H., M.D. 56 Harley-street, W.; and Guy's Hospital, London, S.E.
1879. §Pye-Smith, R. J. 7 Surrey-street, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.
1870. ‡Rabbits, W. T. Forest Hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. §§Radford, R. Heber, M.I.C.E. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1878. ‡Rae, John, M.D., LL.D., F.R.S. 2 Addison-gardens South, Kensington, London, W.

Year of Election.

1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡*Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.*
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. Kilmorey Lodge, 6 Kent-gardens, Ealing, W.
1845. ‡RAMSAY, ANDREW CROMBIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Economic Geology. (PRESIDENT.) Geological Survey Office, Jermyn-street, London, S.W.
1867. ‡*Ramsay, James, jun. Dundee.*
1861. ‡Ramsay, John, M.P. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 39 Hammersmith-road, West Kensington, London, W.
1876. ‡RAMSAY, WILLIAM, Ph.D. Professor of Chemistry in University College, Bristol.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 10 Castletown-road, West Kensington, London, S.W.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. Kempstone Mill, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London. N.W.
RATCLIFF, Colonel CHARLES, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 10 Lorn-road, Brixton, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhall, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *RAWLINSON, Major-General Sir HENRY C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §§RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. Drayton House, West Drayton, Middlesex.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., F.R.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. 5 Salisbury-villas, Cambridge.
1865. ‡*Rayner, Henry. West View, Liverpool-road, Chester.*
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1865. ‡Read, William. Albion House, Epworth, Rawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.

Year of
Election.

1870. §Reade, Thomas Mellard, C.E., F.G.S. Blundellsands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 28 Bold-street, Alexandra-road, Manchester.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. ‡Reed, Sir Edward J., K.C.B., M.P., F.R.S. 74 Gloucester-road, South Kensington, London, W.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1878. §Reichel, The Ven. Archdeacon, D.D. The Archdeaconry, Trim, Ireland.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1874. ‡*Reid, Robert, M.A. 35 Dublin-road, Belfast.*
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1875. §Reinold, A. W., M.A., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1871. ‡Reynolds, James Emerson, M.A., F.R.S., F.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *Reynolds, Osborne, M.A., F.R.S., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. ‡Rhodes, John. 358 Blackburn-road, Accrington, Lancashire.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1868. §§Richards, Vice-Admiral Sir George H., C.B., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.
1863. ‡Richardson, Benjamin Ward, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 6 Victoria-terrace, Worthing.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J. H. 3 Arundel-terrace, Cork.
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
1861. ‡Richardson, William. 4 Edward-street, Werneth, Oldham.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1863. ‡Richter, Otto, Ph.D. 6 Derby-terrace, Glasgow
1870. ‡*Rickards, Dr. 36 Upper Parliament-street, Liverpool.*
1868. §§Ricketts, Charles, M.D., F.G.S. 22 Argyle-street, Birkenhead.
1877. ‡Ricketts, James, M.D. St. Helen's, Lancashire.
*Riddell, Major-General Charles J. Buchanan, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1872. ‡Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1873. ‡Ripley, Edward. Acacia, Apperley, near Leeds.
1873. ‡Ripley, Sir Henry William, Bart. Acacia, Apperley, near Leeds.

Year of Election.

*Ripon, The Most Hon. the Marquis of, K.G., D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Babbicombe, near Torquay.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, John, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878.§§Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1859. ‡Roberts, George Christopher. Hull.
1870. *Roberts, Isaac, F.G.S. Kennessee, Maghull, Lancashire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1879.§§Roberts, Samuel. The Towers, Sheffield.
1879.§§Roberts, Samuel, jun. The Towers, Sheffield.
1879.§§Roberts, Thomas. The Knowle, Park-lane, Sheffield.
1868. §Roberts, W. Chandler, F.R.S., F.G.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal School of Mines. Royal Mint, London, E.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1876. ‡*Robertson, Andrew Carrick. Woodend House, Helensburgh, N.B.*
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. 4 Albert-road, Southport.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1866. ‡Robertson, William Tindal, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.
1873. §Robinson, Hugh. 82 Donegall-street, Belfast.
1861. ‡Robinson, John, C.E. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1878. ‡Robinson, John L., C.E. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1875. *Robinson, Robert, C.E., F.G.S. 2 West-terrace, Darlington.
1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
Robinson, Rev. Thomas Romney, D.D., F.R.S., F.R.A.S., Hon. F.R.S.E., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 41 Parliament-street, Westminster, S.W.
1876. ‡Robson, Hazleton R. 14 Royal-crescent West, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1872. §Rodwell, George F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1860. ‡Rogers, James E. Thorold, M.P., Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 87 South-street, Exeter.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.

Year of
Election.

1859. ‡ROLLESTON, GEORGE, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1876. §§ROLLIT, A. K., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1876. ‡Romanes, George John, M.A., F.R.S., F.L.S. 18 Cornwall-terrace, Regent's Park, London, N.W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1863. ‡Roseby, John. Haverholm House, Brigg, Lincolnshire.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1880. §Ross, Captain. 170 Cromwell-road, London, S.W.
1857. ‡Ross, David, LL.D. 32 Nelson-street, Dublin.
1872. ‡Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1874. ‡Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.
1880. §Ross, William Alexander. Acton House, Acton, London, N.
1869. *ROSSE, The Right Hon. the Earl of, B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1861. ‡Routh, Edward J., M.A., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)
1861. ‡Rowan, David. Elliot-street, Glasgow.
1877. §ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1880. §Rowly, Christopher. Cirencester.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College Galway. Salerno, Salthill, Galway.
*Rowntree, Joseph. 12 Heslington-road, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1875. ‡Rücker, A. W., M.A., Professor of Mathematics and Physics in the Yorkshire College, Leeds.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1873. ‡Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford, Yorkshire.
1847. ‡RUSKIN, JOHN, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1876. *Russell, George. 103 Blenheim-crescent, Notting Hill, London, W.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
Russell, John. 39 Mountjoy-square, Dublin.
RUSSELL, JOHN SCOTT, M.A., F.R.S. L. & E. Sydenham, S.E.

Year of
Election.

1852. **Russell, Norman Scott, Sydenham.*

1876. §Russell, R., C.E., F.G.S. 1 Sea View, St. Bees, Carnforth.

1862. §RUSSELL, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.

1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Professor of Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.

1875. ‡*Rutherford, David Greig. Surrey House, Forest Hill, London, S.E.*

1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.

Rutson, William. Newby Wiske, Northallerton, Yorkshire.

1879.§§Ruxton, Captain Fitzherbert, R.N. 41 Cromwell-gardens, London, S.W.

1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.

1874. §Rye, E. C., F.Z.S., Librarian R.G.S. 70 Charlewood-road, Putney, S.W.

1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.

1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

SABINE, General Sir EDWARD, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.

1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.

1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.

1880. §Sakurai, J. 96 Camden-street, London, N.W.

Salkeld, Joseph. Penrith, Cumberland.

1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.

1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.

1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Brookland Avenue, Cambridge.

1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.

1861. *Samson, Henry. 6 St. Peter's-square, Manchester.

1861. *Sandeman, Archibald, M.A. Tulloch, Perth.

1876. ‡Sandeman, David. Woodlands, Lenzie, Glasgow.

1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.

1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.

1871. ‡Sanders, William R., M.D. 11 Walker-street, Edinburgh.

1872. ‡SANDERSON, J. S. BURDON, M.D., F.R.S., Professor of Physiology in University College, London. 26 Gordon-square, London, W.C.

Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.

1864. ‡Sandford, William. 9 Springfield-place, Bath.

1854. ‡Sandon, The Right Hon. Lord, M.P. 39 Gloucester-square, London, W.

1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.

1865. ‡*Sargant, W. L. Edmund-street, Birmingham.*

1868. ‡Saunders, A., C.E. King's Lynn.

1846. ‡SAUNDERS, TRELAWNEY W. India Office, London, S.W.

1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.

1860. *Saunders, William. 3 Gladstone-terrace, Brighton.

1871. §Savage, W. D. Ellerslie House, Brighton.

1872. *Sawyer, George David. 55 Buckingham-place, Brighton.

1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.

1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.

Year of Election.

1879. *Schäfer, E. A., F.R.S., M.R.C.S., Assistant Professor of Physiology in University College, London. Boreham Wood, Elstree, Herts.

*Schemmann, J. C. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)

1880. *Schemman, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)

1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.

1874. §§Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.

1876. ‡Schuman, Sigismond. 7 Royal Bank-place, Glasgow.

SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.

1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S. Sunnyside, Upper Avenue-road, Regent's Park, London, N.W.

1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.

1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., Sec. Zool. Soc. (GENERAL SECRETARY.) 11 Hanover-square, London, W.

1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.

1878. §§Scott, Arthur William. St. David's College, Lampeter.

1876. ‡Scott, Mr. Bailie. Glasgow.

1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.

1872. ‡Scott, Major-General H. Y. D., C.B., R.E., F.R.S. Sunnyside, Ealing, W.

1871. ‡*Scott, James S. T. Monkrigg, Haddingtonshire.*

1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.M.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.

1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.

1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.

1864. ‡*Scott, Wentworth Lascelles. Wolverhampton.*

1858. ‡Scott, William. Holbeck, near Leeds.

1869. §Scott, William Bower. Chudleigh, Devon.

1859. ‡Seaton, John Love. Hull.

1877. ‡*Seaton, Robert Cooper, B.A. Dulwich College, Dulwich, Surrey, S.E.*

1880. §Sedgwick, Adam, B.A. Trinity College, Cambridge.

1880. §Seebohm, Henry, F.L.S., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.

1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 14 Oppidans-road, Primrose Hill, London, N.W.

1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.

1879. §Selim, Adolphus. 21 Mincing-lane, London, E.C.

1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.

1858. *Senior, George, F.S.S. Rosehill, Dodworth, near Barnsley.

1870. *Sephton, Rev. J. 92 Huskisson-street, Liverpool.

1875. §Seville, Thomas. Elm House, Royton, near Manchester.

1873. ‡Sewell, Rev. E., M.A., F.G.S., F.R.G.S. Ilkley College, near Leeds.

1868. ‡Sewell, Philip E. Catton, Norwich.

1861. **Seymour, Henry D. 209 Piccadilly, London, W.*

*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.

1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.

1867. §Shanks, James. Dens Iron Works, Arbroath, N.B.

1869. *Shapter, Dr. Lewis, LL.D. The Barnfield, Exeter.

Year of Election.

1878. ‡Sharp, David. Thornhill, Dumfriesshire.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡SHARP, SAMUEL, F.G.S., F.S.A. Great Harrowden Hall, near Wellingborough.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1878. ‡Shelford, W., C.E. 35A Great George-street, Westminster, S.W.
1839. Shepard, John. 4 Highfield-place, Manningham, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1880. §Shida, R. 1 St. James's-place, Hillhead, Glasgow.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1870. *SHOOLBRED, JAMES N., C.E., F.G.S. 3 Westminster-chambers, London, S.W.
1875. ‡Shore, Thomas W., F.C.S. Hartley Institution, Southampton.
1861. *Sidebotham, Joseph. The Beeches, Bowdon, Cheshire.
1877. *Sidebotham, Joseph Watson. The Beeches, Bowdon, Cheshire.
1873. ‡Sidgwick, R. H. The Raikes, Skipton.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1856. *SIEMENS, C. WILLIAM, D.C.L., LL.D., F.R.S., F.C.S., M.I.C.E. 12 Queen Anne's-gate, Westminster, S.W.
1878. ‡Sigerson, Professor George, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1865. ‡Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. §§Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1847. ‡Simon, John, C.B., D.C.L., F.R.S., F.R.C.S., Medical Officer of the Privy Council. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
1876. ‡Simpson, Robert. 14 Ibrox-terrace, Glasgow.
*Simpson, Rev. Samuel. Kingston House, Chester.
Simpson, William. Bradmore House, Hammersmith, London, W.
1876. ‡Sinclair, James. Titwood Bank, Pollockshields, near Glasgow.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.

Year of Election.

1870. *Sinclair, W. P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Mahendra Lal, M.D. 51 Sankaritola, Calcutta. (Care of Messrs. S. Harraden & Co., 3 Hill's-place, Oxford-street, London, W.)
1865. ‡Sissons, William. 92 Park-street, Hull.
1879.§§Skertchly, Sydney B. J., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. Exley House, near Halifax.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1870. ‡Slater, W. B. 42 Clifton Park-avenue, Belfast.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.R.M.S. Clifton, Bristol.
1849.§§Sloper, George Elgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860.§§Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1872. ‡Smale, The Hon. Sir John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smeiton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1876.§§Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1868. ‡*Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey, S.E.*
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh. 64 Gower-street, London, W.C.
1873. ‡Smith, C. Sidney College, Cambridge.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1876. ‡Smith, George. Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*SMITH, HENRY JOHN STEPHEN, M.A., LL.D., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford, and Keeper of the University Museum. The Museum, Oxford.
1860. *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.
1870. ‡*Smith, James.* 146 *Bedford-street South, Liverpool.*
1871. *Smith, John Alexander, M.D., F.R.S.E. 10 Palmerston-place, Edinburgh.
1876. *Smith, J. Guthrie. 173 St. Vincent-street, Glasgow.
1874. ‡Smith, John Haigh. Beech Hill, Halifax, Yorkshire.
Smith, John Peter George. Sweyney Cliff, near Coalport, Shropshire.
1871. ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
*Smith, Philip, B.A. The Bays, Parkfields, Putney, S.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan Villa Nova, Shrewsbury.
1847.§§SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.

Year of Election.

*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. §§Smith, William. 12 Woodside-place, Glasgow.
1878. ‡Smithson, Joseph S. Balnagowan, Rathmines, Co. Dublin.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1874. ‡Smyth, Henry, C.E. Downpatrick, Ireland.
1870. ‡Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1878. §Smyth, Mrs. Isabella. Wigmore Lodge, Cullenswood-avenue, Dublin.
1857. *SMYTH, JOHN, jun., M.A., C.E., F.M.S. Lenaderg, Banbridge, Ireland.
1868. ‡*Smyth, Rev. J. D. Hurst.* 13 *Upper St. Giles's-street, Norwich.*
1864. ‡SMYTH, WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 5 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, Lieut.-General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1878. §§Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1879. §SOLLAS, W. J., M.A., F.R.S.E., F.G.S., Professor of Geology in University College, Bristol. 4 The Polygon, Clifton, Bristol.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Park House, Sutton, Surrey.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Starforth House, Barnard Castle.
1879. §Spence, David. Brookfield House, Freyinghall, Yorkshire.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter, F.C.S. Erlington House, Seymour-grove, Manchester.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Springbank, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. ‡Spencer, W. H. Richmond Hill, Clifton, Bristol.
1871. ‡*Spicer, George. Broomfield, Halifax.*
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. §§Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §§Spottiswoode, George Andrew. 29 Ashley-place, London, S.W.
1846. *SPOTTISWOODE, WILLIAM, M.A., D.C.L., LL.D., Pres. R.S., F.R.A.S., F.R.G.S. 41 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 41 Grosvenor-place, London, S.W.

Year of
Election.

1854. *SPRAGUE, THOMAS BOND. 29 Buckingham-terrace, Edinburgh.
1853. ‡Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1879. §§*Stacye, Rev. John. The Hospital, Shrewsbury.*
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1865. §§STANFORD, EDWARD C. C. Glenwood, Dalmuir, N.B.
1837. Staniforth, Rev. Thomas. Storrs, Windermere.
STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
1876. §Starling, John Henry, F.C.S. The Avenue, Erith, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Bradford, Yorkshire.
1857. ‡Steale, William Edward, M.D. 15 Hatch-street, Dublin.
1870. ‡Stearn, C. H. 2 St. Paul's-villas, Rock Ferry, Liverpool.
1863. ‡Steele, Rev. Dr. 35 Sydney-buildings, Bath.
1873. §Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
STENHOUSE, JOHN, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1872. ‡Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
1879. *STEPHENSON, HENRY, J.P. Endcliffe Vale, Sheffield.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. ‡Sterriker, John. Driffield, Yorkshire.
1876. ‡Steuart, Walter. City Bank, Pollockshaws, near Glasgow.
1870. *Stevens, Miss Anna Maria. Belmont, Devizes-road, Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1880. *Stevens, J. Edward. 10 Cleveland-terrace, Swansea.
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1878. ‡Stevenson, Rev. James, M.A. 21 Garville-avenue, Rathgar, Dublin.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1875. *Stewart, James, B.A., M.R.C.P.Ed. Dunmurry, Sneyd Park, near Bristol.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1876. ‡Stirling, William, M.D., D.Sc. The University, Aberdeen.
1867. *Stirrup, Mark, F.G.S. 14 Atkinson-street, Deansgate, Manchester.
1865. *Stock, Joseph S. The Grange, Ramsgate.
1864. §§STODDART, WILLIAM WALTER, F.G.S., F.C.S. Grafton Lodge, Sneyd Park, Bristol.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
*STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.

Year of Election.

1874. ‡Stone, J. Harris, B.A., F.L.S., F.C.S. 11 Sheffield-gardens, Kensington, London, W.
1876. ‡Stone, Octavius C., F.R.G.S. Springfield, Nuneaton.
1859. ‡Stone, Dr. William H. 14 Dean's-yard, Westminster, S.W.
1857. ‡STONEY, BINDON B., C.E., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1878. *Stoney, G. Gerald. 3 Palmerston Park, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 3 Palmerston Park, Dublin.
1876. §Stopes, Henry, F.G.S. 3 Abercromby-place, Edinburgh.
1854. Store, George. Prospect House, Fairfield, Liverpool.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1867. ‡*Storrar, John, M.D. Heathview, Hampstead, London, N.W.*
1859. §Story, Captain James. 17 Bryanston-square, London, W.
1874.§§Stott, William. Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. Stowey House, Clapham Common, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
1879.§§Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
Strickland, William. French Park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1876. *Struthers, John, M.D., Professor of Anatomy in the University of Aberdeen.
1878.§§Strype, W. G., C.E. Wicklow.
1876. *Stuart, Charles Maddock. Sudbury Hill, Harrow.
1872. *Stuart, Rev. Edward A. 22 Bedford-street, Norwich.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873.§§Style, Rev. George, M.A. Giggleswick School, Yorkshire.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Queen's College, Cork.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke, F.R.A.S. Forest Hill Lodge, Warsop, Mansfield, Nottinghamshire.
1879. §Swanwick, Frederick. Whittington, Chesterfield.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.

Year of Election.

SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. Athenæum Club, London, S.W.
1870. ‡SYMES, RICHARD GLASCOTT, A.B., F.G.S. Geological Survey of Ireland, 14 Hume-street, Dublin.
1856. *Symonds, Frederick, M.A., F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., F.R.S., Sec.M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. 7 Great Charles-street, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡TAIT, P. M., F.R.G.S., F.S.S. Oriental Club, Hanover-square, London, W.
1874. §Talmage, C. G., F.R.A.S. Leyton Observatory, Essex, E.
1866. ‡Tarbotton, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1878. ‡TARPEY, HUGH. Dublin.
1861. *Tarratt, Henry W. Mountfield, Grove Hill, Tunbridge Wells.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander, C.E. Longwood, Whitehouse, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1876. ‡Tatlock, Robert R. 26 Burnbank-gardens, Glasgow.
1879. §Tattershall, William Edward. 15 North Church-street, Sheffield.
1864. *TAWNEY, EDWARD B., F.G.S. Woodwardian Museum, Cambridge.
1878. *Taylor, A. Claude. Clinton-terrace, Derby-road, Nottingham.
1874. ‡Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.
1867. ‡Taylor, Rev. Andrew. Dundee.
1880. §Taylor, Edmund. Droitwich.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1879. §Taylor, John. Broomhall-place, Sheffield.
*TAYLOR, JOHN, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. ‡TAYLOR, JOHN ELLOR, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
*TAYLOR, RICHARD, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1878. ‡Taylor, Robert, J.P., LL.D. Corballis, Drogheda.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
*Taylor, William Edward. Hesketh Park, Southport.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.

Year of Election.

1880. §Tebb, Miss. 7 Albert-road, Regent's Park, London, N.W.
1869. ‡Teesdale, C. S. M. Whyke House, Chichester.
1876. ‡Temperley, Ernest. Queen's College, Cambridge.
1879. §Temple, Lieutenant George T., R.N. The Nash, near Worcester.
1880. §Temple, Sir Richard, Bart., G.C.S.I., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
1841. *TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., M.A., B.Sc., F.R.S., F.L.S. 10 Gloucester-road, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1879. *Thomas, Arthur. Endcliffe House, Sheffield.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *THOMAS, CHRISTOPHER JAMES. Drayton Lodge, Redland, Bristol.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. 2 Great George-street, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1880. §Thomas, Joseph William. Penylan, Cardiff.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1859. ‡Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Riversdale, Wilmslow, Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley Hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1876. *Thompson, Richard. Park-street, The Mount, York.
1874. ‡Thompson, Robert. Walton, Fortwilliam Park, Belfast.
1876. §THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.A.S., Professor of Physics in University College, Bristol. 8 Carlton-place, Clifton, Bristol.
1878. ‡Thompson, T. D. Clare Hall, Raheny, Co. Dublin.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S. L. & E. 66 Palace Gardens-terrace, Kensington, London, W.
1850. ‡THOMSON, Sir CHARLES WYVILLE. LL.D., F.R.S. L. & E., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
Thomson, Guy. Oxford.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E., F.R.S. L. & E. Oakfield House, University Avenue, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 3 Abbotsford-place, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1876. ‡Thomson, James R. Dalmuir House, Dalmuir, Glasgow.
1874. ‡Thomson, John. Harbour Office, Belfast.
1871. *THOMSON, JOHN MILLAR, F.C.S. King's College, London, W.C.
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.

Year of
Election.

1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S. L. & E., Professor of Natural Philosophy in the University of Glasgow, The University, Glasgow.
1877. *Thomson, Lady. The University, Glasgow.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1876. ‡Thomson, William. 6 Mansfield-place, Edinburgh.
1871. ‡*Thomson, William Burnes, F.R.S.E. 1 Ramsay-gardens, Edinburgh.*
1880. §Thomson, William J. St. Helen's, Lancashire.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thornburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
*Thornton, Samuel, J.P. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Lyppiatt Lodge, Suffolk Lawn, Cheltenham.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871. ‡THORPE, T. E., Ph.D., F.R.S. L. & E., F.C.S., Professor of Chemistry in Yorkshire College, Leeds.
1868. ‡THUILLIER, Lieut.-General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. 32 Cambridge-terrace, Hyde Park, London, W.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A.. F.G.S. 28 Jermyn-street, London, S.W.
1874. ‡Tilden, William A., D.Sc., F.R.S., F.C.S. Clifton College, Bristol.
1873. ‡Tilghman, B. C. Philadelphia, United States.
1865. ‡Timmins, Samuel, J.P., F.S.A. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNE, JOHN A., F.R.G.S. Briarley, Aigburth, Liverpool.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1861. *TODHUNTER, ISAAC, M.A., F.R.S., Principal Mathematical Lecturer at St. John's College, Cambridge. Brookside, Cambridge.
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡*Tone, John F. Jesmond-villas, Newcastle-on-Tyne.*
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. §§Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John, M.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875. §Torr, Charles Hawley. Harrowby House, Park-row, Nottingham.
1863. ‡Torrens, Colonel Sir R. R., K.C.M.G. 2 Gloucester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. Avenue House, Cotham Park, Bristol.
1857. *TOWNSEND, Rev. RICHARD, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.

Year of Election.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡TOWSON, JOHN THOMAS, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1877.§§Tozer, Henry. Ashburton.
1876. *Trail, Professor J. W. H., M.A., M.D., F.L.S. University of Aberdeen, Old Aberdeen.
1870. ‡TRAILL, WILLIAM A., M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. ‡Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., Professor of Zoology. Museum of Science and Art, Edinburgh.
1835. Travers, Robert, M.B. Williamstown, Blackrock, Co. Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
Tregelles, Nathaniel. Liskeard, Cornwall.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1871. ‡TRIBE, ALFRED, F.C.S. 14 Denbigh-road, Bayswater, London, W.
1879.§§Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡TRIMEN, HENRY, M.B., F.L.S. British Museum, London, W.C.
1871. ‡TRIMEN, ROWLAND, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1854. ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.
1855.§§Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
1871.§§Turnbull, William, F.R.S.E. 14 Lansdowne-crescent, Edinburgh.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
1875. ‡Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.
1863. *TURNER, WILLIAM, M.B., F.R.S. L. & E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. Ryton-on-Dunsmore, Coventry.
1847. ‡TWISS, Sir TRAVERS, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1865. ‡TYLOR, EDWARD BURNETT, D.C.L., F.R.S. Linden, Wellington, Somerset.
1858. *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1876. *UNWIN, W. C., A.I.C.E., Professor of Hydraulic Engineering. Cooper's Hill, Middlesex.
1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.

Year of Election.

1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. §Ussher, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1854. ‡Varley, Cromwell F., F.R.S. Cromwell House, Bexley Heath, Kent.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. Hatfield, Herts.
1870. ‡Varley, Mrs. S. A. Hatfield, Herts.
1869. ‡Varwell, P. Alphington-street, Exeter.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
1873. *VERNEY, Captain EDMUND H., R.N., F.R.G.S. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart. Lower Claydon, Buckinghamshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1879. §Veth, D. D. Leiden, Holland.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1875. ‡Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.
1856. ‡VIVIAN, EDWARD, M.A. Woodfield, Torquay.
*VIVIAN, H. HUSSEY, M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §§VOELCKER, J. CH. AUGUSTUS, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
1875. ‡Volckman, Mrs. E. G. 43 Victoria-road, Kensington, London, W.
1875. ‡Volckman, William. 43 Victoria-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860. §§Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡*Waddington, John. New Dock Works, Leeds.*
1879. *Wake, Bernard. Abbeyfield, Sheffield.
1870. §§WAKE, CHARLES STANILAND. 70 Wright-street, Hull.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.
1869. *Walford, Cornelius. 86 Belsize Park-gardens, London, N.W.
1849. §WALKER, CHARLES V., F.R.S., F.R.A.S. Fernside, Reigate Hill, Reigate.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1866. *WALKER, J. F., M.A., F.C.P.S., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.G.S., F.R.G.S. 3 Circus, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡*Walkey, J. E. C. High-street, Exeter.*

Year of Election.

1863. ‡WALLACE, ALFRED RUSSEL, F.R.G.S., F.L.S. Waldron Edge, Duppas Hill, Croydon.
1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 138 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.R.G.S., F.L.S. 162 Holland-road, London, W.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.
Walsh, John (Prussian Consul). Dundrum Castle, Co. Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D. Fernleigh, Botanic-road, Belfast.
1879. §§Ward, H. Marshall. Christ's College, Cambridge.
1874. §Ward, John, F.R.G.S. Lenox Vale, Belfast.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Westney. 41 Head-street, Colchester.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida Vale, London, W.
1878. §§Warington, Robert, F.C.S. Harpenden, St. Alban's, Herts.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1875. ‡Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1865. *Warren, Edward P. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
1876. ‡Waterhouse, A. Willenhall House, Barnet, Herts.
1875. *Waterhouse, Major J. Surveyor-General's Office, Calcutta. (Care of Messrs. Trübner & Co., Ludgate-hill, London, E.C.)
1854. ‡Waterhouse, Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1875. §Waters, Arthur W., F.G.S., F.L.S. Woodbrook, Alderley Edge, near Manchester.
1875. ‡Watherston, Alexander Law, M.A., F.R.A.S. Bowdon, Cheshire.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡*Watson, Ebenezer. 16 Abercromby-place, Glasgow.*
1867. ‡Watson, Frederick Edwin. Thickthorne House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
WATSON, HEWETT COTTRELL. Thames Ditton, Surrey.
1873. *Watson, Sir James. Milton-Lockhart, Carluke, N.B.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1879. §WATSON, WILLIAM HENRY, F.C.S. Braystones, near Whitehaven, Cumberland.
1869. ‡Watt, Robert B. E., C.E., F.R.G.S. Ashley-avenue, Belfast.

Year of Election.

1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *WATTS, JOHN, B.A., D.Sc. 57 Baker-street, Portman-square, London, W.
1846.§§Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
1859. *WAVENEY, The Right Hon. Lord, F.R.S. 7 Audley-square, London, W.
*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §WELDON, WALTER, F.R.S.E. Rede Hall, Burstow, near Crawley, Surrey.
1878. §Weldon, Mrs. Walter. Rede Hall, Burstow, near Crawley, Surrey.
1879. §Weldon, W. A. D. Rede Hall, Burstow, near Crawley, Surrey.
1876. §Weldon, W. F. R. St. John's College, Cambridge.
1879. §Wells, Charles A. Etna Iron Works, Lewes.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *WESTERN, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.
1870. §Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
Westhead, John. Manchester.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. ‡Weston, James Woods. Belmont House, Pendleton, Manchester.
1875. *Weston, Joseph D. Dorset House, Clifton Down, Bristol.
1864. ‡WESTROPP, W. H. S., M.R.I.A. Lisdoonvarna, Co. Clare.
1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.

Year of Election.

1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1878. *Wheeler, W. H., C.E. Churchyard, Boston, Lincolnshire.
1879. *Whidborne, George Ferris, M.A., F.G.S. Charante, Torquay.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. Kew Observatory, Richmond, Surrey.
1874. §§Whitaker, Henry, M.D. 33 High-street, Belfast.
1859. *Whitaker, William, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1876. ‡White, Angus. Easdale, Argyleshire.
1864. ‡White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡White, James, F.G.S. 8 Thurloe-square, South Kensington, London, S.W.
1876. *White, James. Overtoun, Dumbarton.
1873. §§White, John. Medina Docks, Cowes, Isle of Wight.
White, John. 80 Wilson-street, Glasgow.
1859. ‡White, John Forbes. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. ‡White, Laban. Blanford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 365 Euston-road, London, N.W.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod, C.E. Drood House, Old Trafford, Manchester.
Whitehouse, William. 10 Queen's-street, Rhyl.
1871. ‡Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
1866. ‡Whitfield, Samuel. Eversfield, Eastnor-grove, Leamington.
1874. ‡*Whitford, William. 5 Claremont-street, Belfast.*
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1870. §Whittem, James Sibley. Walgrave, near Coventry.
1857. *Whitty, Rev. John Irwine, M.A., D.C.L., LL.D. 94 Baggot-street, Dublin.
1874. *Whitwell, Mark. Redland House, Bristol.
*Whitworth, Sir Joseph, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
1870. ‡Whitworth, Rev. W. Allen, M.A. 185 Islington, Liverpool.
1865. ‡Wiggin, Henry. Metchley Grange, Harborne, Birmingham.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1855. ‡Wilkie, John. Westburn, Helensburgh, N.B.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1879. §Wilkinson, Joseph, F.R.G.S. York.
1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay.
*Willert, Alderman Paul Ferdinand. Town Hall, Manchester.
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1872. ‡Willett, Henry, F.G.S. Arnold House, Brighton.
Williams, Charles James B., M.D., F.R.S. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 47 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Harry Samuel, M.A. 1 Gorse Lane, Swansea.
1875. *Williams, Herbert A., M.A. 91 Pembroke-road, Clifton, Bristol.

Year of Election.

1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1870. §WILLIAMS, JOHN, F.C.S. 14 Buckingham-street, London, W.C.
1875. *Williams, M. B. North Hill, Swansea.
1879.§§Williams, Matthew W., F.C.S. 18 Kempsford-gardens, Earl's Court, London, S.W.
Williams, Robert, M.A. Bridehead, Dorset.
1869. ‡WILLIAMS, Rev. STEPHEN. Stonyhurst College, Whalley, Blackburn.
1877. *Williams, W. Carleton, F.C.S. Owens College, Manchester.
1865. ‡Williams, W. M. Belmont-road, Twickenham, near London.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., For. Sec. R.S., F.C.S., Corresponding Member of the French Academy, Professor of Chemistry, and of Practical Chemistry, University College, London. (GENERAL TREASURER.) University College, London, W.C.
1857. ‡Williamson, Benjamin, M.A., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
1876. ‡Williamson, Stephen. 19 James-street, Liverpool.
WILLIAMSON, WILLIAM C., F.R.S., Professor of Natural History in Owens College, Manchester. 4 Egerton-road, Fallowfield, Manchester.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡*Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.*
1859. *Wills, Alfred, Q.C. 12 King's Bench-walk, Inner Temple, London, E.C.
1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
WILLS, W. R. Edgbaston, Birmingham.
1878. ‡Wilson, Alexander S., M.A., B.Sc. 124 Bothwell-street, Glasgow.
1859. ‡Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1874. ‡WILSON, Major C. W., C.B., R.E., F.R.S., F.R.G.S., Director of the Topographical and Statistical Department of the War Office. 5 Lansdowne-terrace, Rodwell, Weymouth.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1861. ‡*Wilson, George Daniel. 24 Ardwick-green, Manchester.*
1875.§§Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1879. §Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1855. ‡Wilson, Hugh. 75 Glasford-street, Glasgow.
1857. ‡Wilson, James Moncrieff. Queen Insurance Company, Liverpool.
1865. ‡WILSON, JAMES M., M.A. The College, Clifton, Bristol.
1858. *Wilson, John. Seacroft Hall, near Leeds.
WILSON, JOHN, F.G.S., F.R.S.E., Professor of Agriculture in the University of Edinburgh. The University, Edinburgh.
1876. ‡Wilson, J. G., M.D., F.R.S.E. 9 Woodside-crescent, Glasgow.
1879.§§Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1861. ‡*Wilson, Thomas Bright. 24 Ardwick-green, Manchester.*
1867. ‡Wilson, Rev. William. Free St. Paul's, Dundee.

Year of Election.

1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1870. ‡*Wilson, William Henry.* 31 *Grove-park, Liverpool.*
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
*Winsor, F. A. 60 Lincoln's-Inn-fields, London, W.C.
1868. ‡Winter, C. J. W. 22 Bethel-street, Norwich.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1863. *Wood, Collingwood L. Freeland, Bridge of Earn, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
*Wood, George B., M.D. 1117 Arch-street, Philadelphia, United States.
1870. *Wood, George S. 20 Lord-street, Liverpool.
1875. *Wood, George William Rayner. Singleton, Manchester.
1856. *WOOD, Rev. H. H., M.A., F.G.S. Holwell Rectory, Sherborne, Dorset.
1878. §Wood, H. Trueman, B.A. Society of Arts, John-street, Adelphi, London, W.C.
1864. †Wood, Richard, M.D. Driffield, Yorkshire.
1871. ‡Wood, Provost T. Barleyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
Wood, William. Edge-lane, Liverpool.
1865. *Wood, William, M.D. 99 Harley-street, London, W.
1861. ‡Wood, William Rayner. Singleton Lodge, near Manchester.
1872. §Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, Major JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1870. ‡Woodburn, Thomas. Rock Ferry, Liverpool.
1850. *Woodd, Charles H. L., F.G.S. Roslyn House, Hampstead, London, N.W.
1865. ‡Woodhill, J. C. Pakenham House, Charlotte-road, Edgbaston, Birmingham.
1871. ‡Woodiwis, James. 51 Back George-street, Manchester.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
1869. ‡Woodman, William Robert, M.D. Ford House, Exeter.
*WOODS, EDWARD, C.E. 3 Great George-street, Westminster, London, S.W.
WOODS, SAMUEL. 5 Austin Friars, Old Broad-street, London, E.C.
*WOODWARD, C. J., B.Sc. 76 Francis-road, Edgbaston, Birmingham.
1866. ‡WOODWARD, HENRY, F.R.S., F.G.S. British Museum, London, W.C.
1870. ‡Woodward, Horace B., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1877. ‡Woollcombe, Robert W. 14 St. Jean d'Acre-terrace, Plymouth.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1872. ‡Woolmer, Shirley. 6 Park-crescent, Brighton.
Worcester, The Right Rev. Henry Philpott, D.D., Lord Bishop of Worcester.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. §§Wormell, Richard, M.A., D.Sc. 165 Loughborough-road, London, S.W.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Care of Rev. J. Worthington, Oak Cottage, Streatham-place, London, S.W.
Worthington, Archibald. Whitchurch, Salop.

Year of Election.

Worthington, James. Sale Hall, Ashton-on-Mersey.
Worthington, William. Brockhurst Hall, Northwich, Cheshire.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1879. §Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.
1871. §§WRIGHT, C. R. A., D.Sc., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1861. *Wright, E. Abbot. Castle Park, Frodsham, Cheshire.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany, and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1866. ‡*Wright, G. H. Heaton Hall, near Derby.*
1876. ‡Wright, James. 114 John-street, Glasgow.
1874. ‡Wright, Joseph. Cliftonville, Belfast.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
*Wright, Robert Francis. Hinton Blewett, Temple-Cloud, near Bristol.
1855. ‡WRIGHT, THOMAS, M.D., F.R.S. L. & E., F.G.S. St. Margaret's-terrace, Cheltenham.
Wright, T. G., M.D. Milnes House, Wakefield.
1876. ‡Wright, William. 101 Glassford-street, Glasgow.
1871. ‡Wrightson, Thomas. Norton Hall, Stockton-on-Tees.
1867. ‡WÜNSCH, EDWARD ALFRED. 146 West George-street, Glasgow.
Wyld, James, F.R.G.S. Charing Cross, London, W.C.
1863. *Wyley, Andrew. 21 Barker-street, Handsworth, Birmingham.
1867. ‡Wylie, Andrew. Prinlaws, Fifeshire.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S., of the Geological Survey of India. Bombay.

1875. ‡Yabbicom, Thomas Henry, C.E. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
Yates, James. Carr House, Rotherham, Yorkshire.
1867. ‡Yeaman, James. Dundee.
1879. §§Yeomans, John. Upperthorpe, Sheffield.
1877. §Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1879. *YORK, His Grace the Archbishop of, D.D., F.R.S. The Palace, Bishopsthorpe, Yorkshire.
1870. ‡YOUNG, JAMES, F.R.S. L. & E., F.C.S. Kelly, Wemyss Bay, by Greenock.
1876. *Young, James, jun., F.C.S. Kelly, Wemyss Bay, by Greenock.
1876. ‡YOUNG, JOHN, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
Younge, Robert, F.L.S. Greystones, near Sheffield.
1868. ‡Youngs, John. Richmond Hill, Norwich.
1876. ‡Yuille, Andrew. 7 Sardinia-terrace, Hillhead, Glasgow.
1871. ‡YULE, Colonel HENRY, C.B. East India United Service Club, St. James's-square, London, S.W.

1878. ‡Zerffi, G. G., Ph.D. 3 Warrington-gardens, Maida Hill, London, W.

CORRESPONDING MEMBERS.

Year of Election.

1871. HIS IMPERIAL MAJESTY THE EMPEROR OF THE BRAZILS.
1870. Professor Van Beneden, LL.D. Louvain, Belgium.
1872. Ch. Bergeron, C.E. 26 Rue des Penthièvre, Paris.
1861. Dr. Bergsma, Director of the Magnetic Survey of the Indian Archipelago. Utrecht, Holland.
1880. Professor Ludwig Boltzmann. Halbärtgasse, 1, Gräz, Austria.
1868. Professor Broca. Paris.
1864. Dr. H. D. Buys-Ballot, Superintendent of the Royal Meteorological Institute of the Netherlands. Utrecht, Holland.
1861. Dr. Carus. Leipzig.
1864. M. Des Cloizeaux. Paris.
1855. Dr. Ferdinand Cohn. Breslau, Prussia.
1871. Professor Dr. Colding. Copenhagen.
1873. Signor Guido Cora. 17 Via Providenza, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. J. M. Crafts, M.D.
1876. Professor Luigi Cremona. The University, Rome.
1872. *Professor M. Croullebois. 18 Rue Sorbonne, Paris.*
1874. M. Ch. D'Almeida. 31 Rue Bonaparte, Paris.
1866. Dr. Geheimrath von Dechen. Bonn.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1872. Professor G. Devalque. Liége, Belgium.
1870. Dr. Anton Dohrn. Naples.
Professor Dumas. Paris.
1876. Professor Alberto Eccher. Florence.
1848. Professor Esmark. Christiania.
1861. Professor A. Favre. Geneva.
1874. Dr. W. Feddersen. Leipzig.
1872. W. de Fonvielle. Rue des Abbesses, Paris.
1856. *Professor E. Frémy. Paris.*
1842. M. Frisiani.
1866. Dr. Gaudry, Pres. Geol. Soc. of France. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1870. Governor Gilpin. Colorado, United States.
1876. Dr. Benjamin A. Gould, Director of the Argentine National Observatory, Cordoba.
1852. Professor Asa Gray. Cambridge, United States.
1866. Professor Edward Grube, Ph.D. Breslau.
1871. Dr. Paul Gussfeldt, of the University of Bonn. 33 Meckenheimerstrasse, Bonn, Prussia.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1876. Professor Ernst Haeckel. Jena.
1872. Professor James Hall. Albany, State of New York.
1864. M. Hébert, Professor of Geology in the Sorbonne, Paris.
1877. Professor H. L. F. Helmholtz. Berlin.

Year of Election.

1868. A. Heynsius. Leiden.
1872. J. E. Hilgard, Assist.-Supt. U.S. Coast Survey. Washington.
1861. Dr. Hochstetter. Vienna.
1876. Professor von Quintus Icilius. Hanover.
1867. Dr. Janssen, LL.D. 21 Rue Labat (18° Arrondissement), Paris.
1876. Dr. W. J. Janssen. The University, Leiden.
1862. Charles Jessen, Med. et Phil. Dr., Professor of Botany in the University of Greifswald, and Lecturer of Natural History and Librarian at the Royal Agricultural Academy, Eldena, Prussia.
1876. Dr. Giuseppe Jung. Milan.
1877. M. Akin Kàroly. 5 Babenbergerstrasse, Vienna.
1862. Aug. Kekulé, Professor of Chemistry. Ghent, Belgium.
1866. Dr. Henry Kiepert, Professor of Geography. Berlin.
1873. Dr. Felix Klein. Munich, Bavaria.
1874. Dr. Knoblauch. Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
Laurent-Guillaume De Koninck, M.D., Professor of Chemistry and Palæontology in the University of Liége, Belgium.
1877. Dr. Hugo Kronecker, Professor of Physiology. 57 Sidonien-strasse, Leipzig.
1876. Professor von Lasaulx. Breslau.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1877. Dr. M. Lindeman, Hon. Sec. of the Bremen Geographical Society, Bremen.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1857. Professor Elias Loomis. Yale College, New Haven, United States.
1871. Professor Jacob Lüroth. Technische Hochschule, Munich.
1871. Dr. Lütken. Copenhagen.
1869. Professor C. S. Lyman. Yale College, New Haven, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1867. Professor Ch. Martins, Director of the Jardin des Plantes. Montpellier, France.
1862. Professor P. Merian. Bâle, Switzerland.
1846. Professor von Middendorff. St. Petersburg.
1848. Professor J. Milne-Edwards. Paris.
1855. M. l'Abbé Moigno. Paris.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
1864. Dr. Arnold Moritz. St. Petersburg, Russia.
1856. Edouard Morren, Professeur de Botanique à l'Université de Liége, Belgium.
1875. Dr. T. Nachtigal. Berlin.
1866. Chevalier C. Negri, President of the Italian Geographical Society, Turin, Italy.
1864. Herr Neumayer. Deutsche Seewarte, Hamburg.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1874. M. A. Niaudet. 6 Rue du Seine, Paris.
1848. Professor Nilsson. Lund, Sweden.
1856. M. E. Peligot, Memb. de l'Institut, Paris.
1861. Professor Benjamin Pierce. Washington, United States.
1857. Gustav Plarr. 22 Hadlow-road, Tunbridge, Kent.
1870. Professor Felix Plateau. Rue du Casino, 15, Gand, Belgium.
1868. Professor L. Radkofer, Professor of Botany in the University of Munich.
1872. Professor Victor von Richter. St. Petersburg.
1873. Baron von Richthofen, President of the Berlin Geographical Society. 71 Steglitzer-strasse, Berlin.
M. de la Rive. Geneva.

Year of
Election.

1866. F. Röemer, Ph.D., Professor of Geology and Palæontology in the University of Breslau. Breslau, Prussia.
1850. Professor W. B. Rogers. Boston, United States.
1857. Baron Herman de Schlagintweit-Sakünlünski. Jaegersberg Castle, near Forchheim, Bavaria.
1857. Professor Robert Schlagintweit. Giessen.
1874. Dr. G. Schweinfurth. Cairo.
1872. Professor Carl Semper. Wurzburg, Bavaria.
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